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GEOLOGICAL WORK ON THE WESTERN FRONT

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WHEN the war started in 1914 the army consisted almost entirely of fighting men, and pure scientists did not figure greatly in the original expeditionary force. Gradually, however, the need for men who had expert knowledge on different scientific subjects became apparent. The majority of the scientific departments started in the early months of 1915.

In April 1915 Major-General W. A. Liddell, who at that time was Deputy-Director of Works at G.H.Q., wrote over to the War Office for a geologist to give advice on questions relating to water supply in the area we were then occupying in Northern France and Flanders, and also to collect information regarding the existing and available sources in the ground ahead of our lines in the event of an advance through Belgium.

I was fortunate enough to be appointed to this post, but did not proceed at once to France. About six weeks were spent in London—mostly at the Geological Survey Office—looking over existing literature and trying to help the Director (Sir Aubrey Strahan) who was preparing a report for the War Office on "Geological conditions affecting the available sources of water in Belgium and Northern France." It was not until June 1915 that I proceeded overseas to take up the post of geologist in the Engineer-in-Chief's Office at G.H.Q.

In May 1916 Lieut.-Colonel T. W. Edgeworth David (Professor of Geology in the University of Sydney) arrived in France with the "Australian Mining Corps" which had been organized for Gallipoli. Colonel David had been largely responsible for the formation of this corps, which consisted of three companies and a H.Q. staff. The H.Q. was not merely an administrative staff, but also had scientific and engineering experts for giving advice on geology, listening, boring, electric machinery, etc.

Colonel David remained with this corps until he met with an accident on 25 September 1916; during this time he acted as geological adviser to the Controllers of Mines of the First, Second, and Third Armies. On his

return from hospital he was transferred to the Inspector of Mines Office at G.H.Q.

Lieut. Loftus Hills (Assistant Government Geologist of Tasmania), was working under Colonel David's directions from September 1916. He had immediate supervision of the test-boring which was being carried out for dugouts, etc. During the war an aggregate of some 28,000 feet of test-bores were made under his direction.

Until the end of September 1918 Colonel David, Lieut. Hills, and myself were the only geologists working on the British front. During October 1918 Lieut. G. A. Cook, M.C., and Lieut. C. S. Honman of Australian Tunnelling Companies were lent to G.H.Q. to aid in the preparation of geological maps, etc., which were being asked for owing to the advance into new country.

Until quite near the end of the war Colonel David was under the Inspector of Mines, while I was under the Engineer-in-Chief. This meant that I was not directly under Colonel David, but fortunately my office was quite near his, and later I shared an office with him. This was a great advantage to me, as any one who knows him can well imagine. His work was largely concerned with the mining and dug-outs, while mine was mainly dealing with problems of water supply, but I always got much help from him in any work I was doing. and we frequently went out together when any field work was to be done.

Fortunately the geology of Northern France and Flanders is not very complex, or it would have been quite impossible for so small a staff to attempt to cope with the work. Generally speaking, there is first the coastal plain to Dixmude and the Yser, then there follows the Flanders plain, with a range of isolated peaks from Cassel to Kemmel and the hills of Renaix, with the secondary lower ridge of Messines–Passchendaele, and then to the south of the flat plain of the Lys begins the chalk hill country of Artois and Picardy.

The geological structure and topography are intimately connected. A glance at the map shows several striking features: the coastal plain, the isolated hills of Flanders, the chalk hills rising from the plain, and the marked alignment of the rivers of Picardy.

The coastal plain lies below high-tide level, and is only protected from the sea by the line of sand-dunes and by the locks at the mouths of the rivers and canals. It was thus possible to maintain the inundations of the Yser by manipulating the locks and sluices near Nieuport. A point of historic interest, in showing that the sea has only in recent years been kept from the plain, is that the point of departure of Julius Cæsar and his fleet was near Watten, now 13 miles from the coast.

The next striking feature is the range of isolated hills from Cassel to Renaix. Each of these hills is formed of sand, with a capping of ferruginous sands, with iron-cemented sandstone of the Diestian period. It would appear that these hills are the remnant of the cuesta of the Diestian, for

there is no evidence of the hills being due to any folding or faulting. The Messines–Passchendaele ridge, then, would be the secondary watershed between the drainage of the Yser and that of the Lys.

The chalk hills of Artois rise from the plain by the normal northerly dip of the strata; some of the more marked features, like the Notre Dame de Lorette and Vimy ridges, are due to faulting and folding. Under the plateau of Picardy the chalk is not lying horizontal, but in gentle undulations which trend in a general north-west to south-easterly direction. It would appear, as has been pointed out by the French geologists, that this folding is responsible for the remarkable parallel alignment of the rivers.

Naturally, during the war it did not matter to an army whether, for instance, Kemmel Hill was a remnant of a cuesta or what it was. As the hill was there, the question of importance was, whereabouts on the hill dug-outs should be made and where wells should be sunk. In many cases sites which would have been the best from geological considerations might not have suited the military requirements; therefore the geologist must know the military as well as the practical scientific side of the question.

It might be well to illustrate the type of geological work done at the front by giving examples, starting at the coast at Nieuport and working southwards towards Noyon.

Nieuport is situated at the mouth of the Yser on the coastal plain just inside the Dune barrier. Here we held both banks of the Yser in September 1917; inquiries were started to ascertain if it were possible to construct a subway under the Yser. The geological evidence afforded by some bores for water in the district indicated that the Ypresian (London or "Blue") clay would be at a depth of at least 50 to 60 feet beneath wet running sands. It was then decided to test the depth to the clay. The work was done by the 2nd Australian Tunnelling Coy. by a waterflush method of boring. Blue clay was reached at 87 feet on one side of the channel and 102 feet at the other; but these depths were too great to permit of the construction of the tunnel, as the shafts would have had to have been over 100 feet deep.

The Ypres salient was the most difficult area in which to carry out the type of geological work which is of use to an army.

This largely arose from the way the strata changed from one point to another. A bed which at one point would be a good clay passed laterally into a sandy clay with thin seams of sand which allowed water to soak through, or perhaps a good sand which drained naturally would begin to have thin clay seams which held up the water. To complicate things further, there was a covering of recent sands, loams, and alluvial muds of varying thickness over the whole country. Colonel David prepared a series of geological maps on the scale of 1 : 10,000 of almost the whole of the district, and as further information came in from the numerous test-borings which were made and other sources, new editions were brought

out. These maps gave indications as to which areas were likely to be good for dug-outs and which were probably bad, but the ground had always to be tested before a definite answer could be made. It must be noted that these maps were made essentially for dug-out work, and it did not necessarily mean that a place where the surface was wet was bad for a dugout, for the ground just above a good clay band would naturally be one of the wettest spots and yet be an excellent locality for starting a dug-out. This is a point which does not seem to have been always borne in mind by those who got hold of the maps.

The question of water-supply in the Ypres salient and the rest areas behind the fighting zone was always difficult. Even in peace-time Ypres had a water supply from Dickebuish Pond and Zillebeek Lake; all attempts to obtain a good supply from the sand-beds of the Messines ridge had been unsuccessful, and surface water collected in these two shallow lakes had to be used.

The water from these lakes was used, but owing to its nearness to the line large engineering works could not be maintained in working order. Moreover, the water was highly contaminated and needing much purification. The villages and farms obtained sufficient water for their peace-time needs from shallow wells about 10 to 20 feet deep in the surface loams and alluvial deposits. As a rule, however, each well was only capable of yielding 100 gallons a day, or just enough to fill one water-cart. The quality of the water from many of these wells was poor, and frequently the drainage from manure heaps and cess pits soaked into the well.

The springs from the sands of the Mont des Cats and Mont Rouge range were collected and piped down to convenient places, but although they supplied a local need, the volume of water was not great enough to help the area beyond Poperinghe. Only two other solutions were possible: boring and purified surface water. As regards boring, the geological structure made it almost impossible to supply large numbers of troops and horses with water, therefore surface water had to be used, and large alum sedimentation and purification works were made on the Yser near Haringe and the water pumped through iron mains up into the forward areas. By means of borings, however, good water could be obtained in small quantities. In this part of Flanders the only water-bearing horizon is in the Landenian sands. This sand is found at about 300 feet below sea-level, or 400 feet below the surface, beneath the thick mass of impervious blue Ypresian clay; the sand-bed is from 30 to 50 feet thick, below which is more clay, and then a thin impervious bed of chalk resting on old Palæozoic slate rocks.

This geological structure was known from several existing bores in Belgium and Northern France, the records of which were either obtained from publications or from information collected on the ground. It was possible to estimate fairly accurately the depth at which the sand would

be struck. This was useful, because drilling could be carried on to within a short distance of the top of the sands before the 6-inch casing was lowered down. By this method boring was more rapid, as the clay stood well enough unlined for a few days. When the sand was reached the water rose in the bore to near the surface, and in one or two bores actually flowed as in a true artesian well. The water was of excellent quality and beautifully soft, but there was one great objection to this source of supply. The sand which held the water was extremely fine, and when the borehole was pumped at a rate of more than 300 to 400 gallons an hour the sand was floated up with the water, and in a short time the washers of the pump were cut to pieces and the bore choked with fine sand.

Bores into these sands were also made to the south of the Cassel–Kemmel hills, chiefly near Hazebrouck, Bailleul and Neuve Eglise. At several of these bores experiments were tried both by Major A. J. Smith and by Captain J. L. Adams, who had charge of water supply and the boring section respectively in the Second Army, and also by the Australian Electrical Mechanical Mining and Boring Company. Some of these experiments are of interest and may be described here.

The problem resolved itself into two parts: firstly, the finding of a method of preventing fine sand entering the bore at a depth of anything from 200 to 400 feet below the surface: and secondly, of arriving at the quantity of water it was possible to obtain from the bore in a day without permanently lowering the water-level. It must be noted that the boring machines available were not designed to make holes of more than 8 inches diameter, and the casing available for lining the bores was either 6 inches or 8 inches in diameter.

The diameter of the bore at the sands was usually 6 inches. In one case, at Houtkerque, the end of the casing was left open in the sand and water was raised by means of an air-lift pump, but large quantities of sand were blown out with the water, forming a large cavity at the foot of the 6-inch pipe. At Neuve Eglise a similar method was tried with a much smaller air compressor; this yielded 450 gallons an hour of fairly clean water.

The other method of raising water was with the ordinary type of tube-well pump made to lift 1000 gallons an hour. With these pumps a filter or strainer was always used. Several types were tried. Firstly brass gauze with sixty meshes to the linear inch, but it was found that this was of little use, as it only held back 15 to 30 per cent. of the sand when tested with a sample at the surface. Then a second type of filter was tried, which was made by wrapping a cloth made of horsehair round the perforated end-piece of the tube; this only gave slightly better results than the brass.

At this time a set of grading sieves was obtained varying from 10 to 180 wires to the inch. Samples of sand were taken from various bore-

holes and from surface outcrops; these were graded and diagrams drawn up to show the percentage of sand which would pass through any given sized aperture.

From these diagrams we arrived at the greatest possible opening consistent with keeping back the necessary percentage of sand to prevent the formation of a cavity behind the strainer. The reason for the need of preventing "cavitation," as it has been called, is that once a cavity forms all hope of forming a natural filter of the larger grains outside the strainer is lost.

The ideal arrangement is to have the strainer, then a zone of grains of the coarser portions of the sand, and then the natural undisturbed sand. The type of strainer used for this was one invented by Mr. Ashford and it had been used by him with great success in India. It consisted of an octagonal column of rods kept in place by steel rings and wound round on the outside with copper wire, each wire being a fraction of an inch from its neighbour. The results of the experiments with the grading sieves showed that the spaces between the wires should not be greater than 4/1000 to 6/1000 of an inch. For 50 feet of strainer these minute gaps added up to be equivalent to an opening of 400 square inches. A test hole was made at Cunewele, near Hazebrouck, and worked with a 60 cubic feet compressor and 2-inch rising main. The result was 1000 gallons an hour of perfectly clear water.

The second problem, of the quantity of water it was possible to obtain from a bore in a day, arose from some bores in the Bailleul district giving out. The failure of a well was not a sudden happening, and the indications seemed to be that when, after several hours' rest, the water fails to return to its former level, the sands in the neighbourhood of the bore are being "dried out" owing to the slowness of the percolation of the water through the excessively fine sand. In other words, a zone of sand which is not fully saturated with water is being produced round the bore. The daily yield of bores in this sand appeared to be between 6000 and 10,000 gallons a day without lowering the rest level of the water to any serious extent.

To the south of the Ypres salient came the line of hills from Cassel to Kemmel and the Messines ridge. Where the line crossed this ridge from Hill 60 to Ploegstreet was the great system of mines which added so much to the success of the offensive of 7 June 1917. A report written by Colonel David gives the following:

"One of the most difficult mines to construct was that of Boyle's Farm, between Wulverghem and Messines, extending to Ontario Farm, the latter being strongly held by the enemy. The difficulty arose chiefly from the great thickness (93 feet) of water-bearing alluvials, chiefly sands and sandy clays, overlying the Blue clay in which the driving of galleries was possible. Two unsuccessful attempts were made to sink shafts through the running sands. Then, the most favourable spot having been selected,

as the result of the evidence of geological test bores, a third attempt was made, which eventually proved successful. The mining system was developed by the 171st Tunnelling Company R.E., under Major Hudspeth, steel tubing being sunk through the running alluvials well down into the Ypresian clay (Blue clay). When the gallery had reached a point at about 480 feet distant from the bottom of the Winze shaft, the clay in the roof softened, and water with sand started to come in. With great promptitude the end of the gallery was sealed off. A careful geological examination was now made, with a view to estimating the exact maximum depth of the old alluvial channel, so as to decide how much deeper the tunnel would have to be carried in order to be safe from the running sand and the gravel. The conclusions were based on a series of bores made by the Belgians, as well as on evidence from our own mine workings in the vicinity, and particularly on the character of a few blocks of shingle up to one foot in diameter which had worked their way down into the clay at the end of our tunnel, and gave good evidence by their coarseness that the very bottom of the channel had been touched at the end of the sealed-off gallery. The gallery was dipped another 7 feet and the bottom of the channel was just cleared, with a sufficiency of clay in the roof to keep back the water. This tunnel was completed, chambered and charged just in time to be fired at the attack of 7 June 1917, and the resulting explosion was very satisfactory.

"Another serious geological difficulty in mining in this zone, apart from the thickness of the Quaternary alluvials of the Petite Douve Valley just mentioned, was the presence of the water-bearing Kemmel Sands. We first identified these sands at Mont Kemmel, where they outcrop between the 70-metres and 60-metres contour. There they formed quite a useful source of water supply on a small scale, but it was impossible to make dugouts or tunnels in them, excepting in the case of small isolated knolls, where natural conditions for drainage were exceptionally good. Traced north-eastwards, the Kemmel Sands gradually dip, so that, on the eastern slopes of Wytschaete Hill, they outcrop between the altitudes of 58 and 48 metres. They are therefore about 10 metres in thickness. The running character of this sand is well seen in the railway cutting at Hill 60. The concussion of exploding mines and bursting shells has caused the banks of the cutting to collapse, and sand and water have flowed inwards from the bases of the slopes of the cutting, partly filling it up. It was these Kemmel Sands that made it impossible to obtain satisfactory dug-outs at Verbrandenmolen, Battle Wood, Shrewsbury Forest, Clapham Junction, Dumbarton Wood, Polygon, and many other areas extending through Zonnebeke along the Passchendaele Ridge.

"With the exception of the mines in the Ploegsteert area, all the rest of the mines were in the sandy clays of the Paniselian formation (so called after Mount Panisel, near Mons, where it is typically developed).

"Some of the mines, such as those of Kruisstraat, Spanbroekmolen and

Peckham, were driven in the sandy clays just below the base of the water-bearing Kemmel Sands. Had geological advice been sought at the time these mines were begun, there would certainly have been a recommendation to sink a little deeper before tunnelling, so as to place the galleries well below the level of the Kemmel Sands, excavating them in the brown to greenish clay which there usually forms the base of the Paniselian formation. This was done, for example, in the case of the mine at Maedelstede Farm, at the Caterpillar (Hill 60 B), and at Hill 60 A, in which the galleries were driven along perhaps the best possible geological horizon.

"At zero (3.50 a.m.) on 7 June 1917 the whole of the nineteen mines, some of which had been commenced eighteen months previously, were exploded simultaneously. It was probably the most spectacular scene in the whole war. It was the grey of early dawn when onlookers, at vantage points where the whole of the mined zone could be seen, suddenly experienced a violent shaking of the ground, the phenomenon being like that of a strong earthquake shock, and as they gazed nineteen gigantic roses with crimson petals seemed to rise slowly and majestically out of the ground. They appeared square rather than round, preserving probably the shape of the mine-chamber from which they were fired. The crimson petals now gave place to a veritable pillar of fire, intensely bright and variously coloured. In a moment dark material could be seen hurtling skyward through the centre of the fire pillars. To those at only a small distance away the explosions, though caused by an expenditure of a million pounds of ammonal, were almost or altogether inaudible.

"Before the fires of the exploding mines had sunk down the big barrage of our guns burst forth, our troops went over the top, and it is a matter of history that the seemingly impregnable hills of Messines and Wytschaete were taken at comparatively slight cost.

"M. Ch. Barrois, the Professor of Geology at the University of Lille, informed us recently that at the time the Messines–Wytschaete mines were fired the whole of the city of Lille experienced what seemed to be a sharp shock of earthquake. He and all his household were awakened by it, and dressed hurriedly in anticipation of possibly a more severe shock following the first. Lille is about 11½ miles distant from the nearest of our mines (that of Ontario). On the morning of the explosion of the mines many German soldiers were to be seen running apparently panic-stricken down the streets of Lille."

The mines of Messines were either in the Ypresian clay or Paniselian clays and sandy clays. Mining operations also went on wherever the Ypresian clay existed, but south of the River Lys the underlying sands were brought into contact with the recent sands and loams at Bois Grenier by an anticlinal flexure which had elevated the beds. In course of time this anticlinal ridge had been levelled down by denudation, and no surface sign of its existence was left. Several borings were made to

CRATER AT ONTARIO FARM AND MESSINES RIDGE

QUICKSAND FLOWING INTO RAILWAY CUTTING AT HILL 60

WATER SUPPLY FOR TROOPS AND HORSES IN A DRY VALLEY

WELL AT LILLERS, REPUTED THE FIRST ARTESIAN WELL EVER SUNK

find the exact edge of the clay and test if it were thick enough to admit of the construction of dug-outs in those places where it still existed.

A strip of country in front of Fleurbaix was found where a sufficient thickness of good clay existed, but it was covered by a layer about 8 to 15 feet thick of water-bearing alluvial sands, while below was Landenian greensand full of water under considerable artesian pressure. By means of steel tubing, shafts were sunk though the sands and a joint made with the clay beneath; the shaft was then sunk until a depth of about 35 feet below the surface of the ground was reached. The dug-outs were then excavated so as to leave about 28 feet of cover. The sands were within about 10 feet of the floor of the dug-out, so that the inhabitants were sandwiched in between the water-bearing alluvial sands above and the Landenian greensand with their artesian water below.

It was at one time proposed to tap the artesian supply of water by boring the floor of the dug-out and fixing a standpipe and tap, but the proposal was abandoned, as it was feared that the water under constant pressure would work its way up along the junction of the pipe with the clay and result in the flooding of the dug-out.

An interesting and extremely valuable piece of work was done by Colonel David at Givenchy lez la Bassée in the basal beds of the Tertiary. An abstract of his account of the work is:

"Previous to the blow [Red Dragon crater blown by the enemy on 22 June 1916] some of our mining galleries in this sector, at Bunny Hutch shaft, had been inundated through the workings having struck the artesian water in the chalk, but there was no accurate record as to the exact depth at which the water horizon had been touched. Accurate letermination of the exact depth to which mining could safely be carried in this important sector now became very urgent.

"The whole operation of making these two bores and sealing them, and tracing the outcrop of a certain fossil shell bed (containing *Cyprina morrisii*), occupied about two days. The evidence of the two bores gave the apparent dip of the strata in one direction, and from that of the outcrop of the shell-bed the apparent dip was found to be in a direction more or less at right angles to the first. From these two directions the true dip was easily calculated, and the exact depth of the artesian water surface was thus determined. From this new datum General Williams laid out a new mining system for the Givenchy Sector, and all underground works at Givenchy from then until the final great defence of Givenchy in June–July 1918 were laid off in reference to this horizon.

"The problem, though of course an extremely simple one, was essentially a geological one, and had the geological examination been made earlier, it is probable that the Red Dragon Crater would never have been blown."

The artesian water referred to above is of special and historic interest. Along the belt of country from Bethune, Chocques, Lillers, etc., beautiful

artesian wells can be found in almost every large farm, and almost every cottage has a lead pipe from which flows excellent water. This water comes from the chalk, which it enters as rain on the hills to the south, but as it works downwards it gets beneath the clay band of the base of the Tertiary beds. This clay dips down under the plain of the Lys, so that the water which is in the chalk cannot rise to its natural level until the clay is pierced by a boring. A well at Lillers has the reputation of being the first flowing well to be made; hence the name "Artesian," from the ancient province of "Artois," of which Lillers formed part.

From the flat valley where these flowing wells are found the ground rises gradually to the south. Here the chalk appears at the surface or is covered by a thin layer of clay-with-flints and loam. From Cuinchy to the Souchez Valley was one almost continuous line of mine galleries. The galleries were all driven in chalk, and were as deep as possible; the limiting factor as to depth being water.

At a certain depth down in the chalk is the underground "water-table." Above this line the chalk is not free from water, though such water as is present is held by capillary attraction in the minute pores of the rock, but below the water-table the chalk is saturated with water, which is held like the water of a wet sponge in the fissures and joints of the rock, and is free to move and circulate.

A gallery driven in the chalk above the water-table is perfectly dry, but any hole made below it at once fills with water. The mine galleries therefore had to be made in the chalk above the water-table. Now the underground water-table is not a fixed stationary surface, but is pulsating up and down with the seasons.

As regards its general shape, the water-table rises under the hills and sinks towards the main river valleys. It was obviously of the greatest importance to discover the cause of this pulsation and to ascertain the amount of seasonal variation of the water-level, so that the dates of the highest and lowest levels could be predicted.

The variation of the water-level depends chiefly on:

1. Rainfall.
2. Evaporation.
3. Run off at the surface:
   (*a*) Superficial in streams.
   (*b*) Underground by means of springs.

The rainfall is more or less evenly distributed over the year, although during the winters rather more falls than at other times of the year. Evaporation behaves, however, very differently. During the winter months practically no evaporation takes place, while in the summer nearly all the rain which falls goes off again under the influence of evaporation, or during heavy storms is discharged direct into the rivers.

In a chalk area nearly all the valleys are "dry," and flowing water is found only in the main river channels which are fed by springs.

These springs are the natural outlet for the waters which are gradually working down from where the water-table is highest.

During the summer, owing to the great evaporation, none, or only a very small proportion, of the rain which falls ever gets down to make good the loss of water at the springs. As a result the water-table falls from a maximum in the spring until late in the autumn. In late autumn evaporation cannot cope with the rain which falls, and this water therefore soaks down into the chalk and begins to replenish the reservoir, which has been lowered during the summer by the escape of the water at the springs.

Actual figures were obtained by Colonel David by making borings in the mine-galleries and collecting data from the tunnelling companies which had been on the ground for some time. Later some very valuable information was obtained from M. Malatray, Chief Engineer of the Compagnie des Mines de Bethune, who gave us curves of the chalk water-level from various mines which had been carefully measured each week for many years. Then, with the help of Colonel Gold, Commandant of the Meteorological Section, who pointed out the importance of the evaporation factor and supplied local rainfall curves, the relationship between the rainfall and the variation in the water-table became very apparent.

Colonel David showed that there is a lag of only from two weeks to a month between the peak of the rainfall (after correcting for evaporation and run off) and that of the chalk water-table. Thanks to this work it was possible to give an accurate estimate of the height to which the water would rise in the spring in the mines from the Hohenzollern Redoubt to the Souchez River. It was found that some of the galleries were too low and would become flooded when the water-table rose. A new system of galleries was commenced at once with a datum line corrected to coincide with the maximum height to which water was expected to rise. The result was that when the water-table was at its highest the floors of some of the galleries were just under water. If it had not been for this work of Colonel David's a large part of our mining system would have been completely flooded out and lost. This might have resulted in great loss of life, as it would have left this part of the front unprotected by a mining system.

The fluctuation of the water-level was also of importance in water-supply schemes. In certain cases the method adopted was to make a pump chamber in the chalk just above highest water-level and have the suction of the pump drawing from a deep borehole in the chalk. In such cases it was necessary to estimate the maximum height to which the water would rise at any time of the year, so as to keep the pump chamber dry. The gradual falling in the water-level throughout the summer and autumn was a source of worry to some of the water-supply officers, especially when rains had no effect on the steady fall of the water, until it

was shown that no rise in the water could be hoped for until late in the autumn. When the date of the turn of the tide was known arrangements could be made accordingly.

The strata of Northern France which overlie the Coal Measures and old rocks are as a rule not affected by great faults or folds, but lie in gentle undulations. The one great exception is the fault-fold of Marqueffles, which is responsible for the Vimy and Notre Dame de Lorette ridges.

At the northern end of the Vimy ridge was the enemy strong point known as "the Pimple." This was found to consist of sand and clay of the same age as those at Givenchy lez la Bassée; these beds had been preserved as a hill on the eastern side of the fault-fold. Our mining system was in the chalk, but a geological section was prepared by Colonel David, and a tunnel was started in the chalk which was to strike the clay under "no man's land," and continue in the clay which permitted of silent working until under the enemy position. The work was started but never completed, as the Canadians took the Pimple by storm in the Battle of Vimy Ridge.

The Marqueffles Fault also had an effect on the conditions for water supply, for it brought the lower beds of the chalk to the surface or near the surface over a considerable area between the Notre Dame de Lorette Ridge on the north, Vimy Ridge on the east, and the line of the high ground north of the Scarpe valley on the south.

In Picardy and Eastern Artois the middle and lower chalk is more of the nature of a clayey marl than of white chalk, and in this state the water does not permeate the whole mass but circulates in the larger fissures. Where these beds are near or at the surface borings for water are practically useless, as the only hope for obtaining a good supply is to strike a fissure. A map was therefore prepared to show where borings were likely to be successful and where they would probably be failures; a certain amount of "doubtful area" was shown where the opinion of a geologist should be got before a boring was started. This type of map was found to be useful and was developed somewhat later.

The problem of supplying water to troops and horses on the waterless areas of the chalk plateau was solved mainly by boring combined with a certain amount of pipe-line.

The work of chalk-boring was reduced to a fine art. There were six boring sections, one with each army, and a section of the Australian Electrical Mechanical Mining and Boring Company. In all, these sections made about 500 boreholes, with an average depth of 300 to 350 feet. Numerous records for speed were made, but on the average it took three to four days to make a 350-foot bore when once the machine had been got to the site. When a 6-inch bore was made in the chalk on a good site the yield with the type of air-compressor used was between 6000 and 12,000 gallons an hour, according to the depth water was struck below

the surface. As was stated above, the middle and lower chalk of Picardy is a clayey marl. The bores nearly always touched this marl, and were frequently made largely in it in order to obtain sufficient submersion for a proper working of the air-lift pump.

In order to get a good yield it was necessary to have a thickness of not less than 50 feet of water-bearing chalk, and bores in hollows generally gave better results than on high ground even when the latter had a greater thickness of water-bearing chalk to draw upon. Thus it may be concluded that the local topography is of as much importance in this area as the general underground geological structure.

However, it was useful to know the general structure of the district, so that with a knowledge of the position of the water-table it would be possible to predict if there would be sufficient water-bearing chalk in an area. A series of curves were drawn which was practically a contour map of the upper surface of the marls. This map was corrected when necessary as fresh information came to hand through borings, and copies were sent out to the water-supply officers in the armies.

As each boring was made a record of the strata, pumping tests, etc., was sent to G.H.Q. and entered up on a card catalogue, so that the information was accessible whenever needed.

Work sometimes, however, was of a more purely scientific nature. When making a dug-out at Morchies, near Bapaume, the remains of a mammoth were discovered. Colonel David went down to visit the site, and returned with a tooth and some chipped flints. On arriving at the place he found every one talking about the mammoth; the war that day was quite a secondary thing in that area. Later Prof. Commont of Amiens discovered a tusk, which showed signs of having been hacked with flint implements. A certain amount of work was done in the Tertiary beds on the edge of the Paris Basin near Noyon, particularly with regard to the possibility of making dug-outs in the clays and sands, and also with regard to the position and character of the chalk of this area from a water-supply point of view.

Besides the field work and indoor work connected with it, a fair amount was done at G.H.Q., more in the nature of Intelligence work. One report by Colonel David was on the general nature of the ground of the country to the north and east of the Passchendaele Ridge and its behaviour under shell fire.

Various maps were also drawn up for those interested in the water supply of areas ahead of our lines. The first of these was a set of maps on the 1/100,000 scale, with all the available information regarding civil supplies of Belgium and Northern France entered up against each village. Information was collected from various sources, and plates prepared for printing by Lieut. R. S. Hortop, R.F.A. (then Corporal R.E.). A second edition was brought out from time to time as additional information became available.

Maps giving the contour of the water-table ahead of our line were also drawn on theoretical grounds, but although extremely inaccurate, they were found to be better than nothing.

The ordinary topographical maps of the area round Cambrai and the Somme show many streams in blue which only exist during heavy rain-storms. A map was therefore prepared to show where the water was to be found at all times of the year.

Maps of a large area on the scale of 1/250,000 were drawn to show where water was plentiful and scarce, and also the quality. It was printed in three colours, each of three different degrees of depth, so that there were nine shades in all, each denoting the quality and quantity of water at any spot. The map was of use as a general guide, but could not be considered at all accurate. In the same way a map was drawn dividing parts of Belgium and Northern France into fifteen provinces, in each of which the conditions of water supply were somewhat different. Notes were prepared to give the general geological conditions of each area, and also Lieut.-Colonel C. G. Du Cane wrote notes as to the type of pumping and other plant which would be needed in each case.

These were of use as showing how the ground varied in front of our line, for those nearer the front had no time to study the ground far ahead of the zone of active operations, and yet the right type of plant had to be available when the time came to occupy the area.

During September 1917 it had been noticed that certain German concrete pill-boxes on the Pimple at the northern end of the Vimy Ridge were made with gravel which could not have come from Belgium, and was probably brought from the Rhine. On returning to G.H.Q. General W. A. Liddell was told about this as a matter of interest and as showing the lack of raw material in the neighbourhood. A few days later the sand and gravel controversy between Holland and Britain appeared in the papers, and General Liddell at once saw the bearing of this evidence on the question. A short note was written on the subject on October 1917, and further specimens were collected, partly by the armies, which were brought over to England to the Geological Survey for a critical examination. A report was drawn up, which was published in a Parliamentary paper in January 1918 on "Transit of Traffic across Holland of Materials susceptible of employment as Military Supplies." The geological examination of the specimens showed that the greater proportion of the gravels used were not of Belgian origin, but contained rocks from the Basin of the Rhine. Among the most characteristic was the "Niedermendig" type of lava, which occurred as freshly quarried pieces of rock.

It is interesting to note that during the war this rock has been used by the Germans in the construction of two large new road and railway bridges over the Rhine between Coblentz and Bonn at Erpel and Engers, and it is probable that specimens found in the concrete were derived from the waste rock in quarrying the large blocks for the masonry work of these bridges.

Besides the work mentioned above, various other problems were dealt with, such as sources for road metal and flint gravel for concrete, foundations for bridges, etc. If it had not been for the existing geological maps and the help we received from many sources, and the comparative uniformity of the ground, it would have been impossible to have covered the area occupied by five armies without an increased staff. Even with conditions as they were, with stationary trench warfare, it was frequently impossible to see as much of the ground as was desirable.

Before the paper the CHAIRMAN (Sir AUBREY STRAHAN) said: Captain King, who was on our Western front for nearly the whole period of the war as a geologist, had much to do with the planning of the various operations of which we have heard in previous meetings. Captain King has been so kind as to come to London for the purpose of giving us the paper which I will now ask him to read.

Captain King then read the paper printed above, and a discussion followed.

The CHAIRMAN: General Liddell, we shall be very pleased to hear some remarks from you. I think you were largely instrumental in getting geologists sent out to the front.

General LIDDELL: I am afraid I am woefully ignorant of geology as a science, but I wish to say, as an old member of the Engineer-in-Chief's Staff and as a former Chief Engineer of an army, how immensely important geological information has proved to be to us in every branch of military engineering. It is a great pity, I think, that we had not more geological information before the war started, but it was rapidly collected by Captain King in the first instance, and then by Colonel David. We owe them an enormous debt of gratitude; their work was most valuable and accurate. In regard to Colonel David, I may say on behalf of R.E. officers that we regarded him always with the most affectionate admiration; he was one of the finest characters we have ever met. The duties that fell to Captain King's lot were multifarious. Water-supply was possibly the most important; and in this connection it would perhaps give you some idea of the problems with which the geologists had to deal when I instance the advance of the Third Army (to which I belonged), from August 21 to November 11. We had to cross practically a desert area, at the northern end about 12 miles, at the southern end about 16 miles broad, in which there was practically no surface water. The water in the chalk was anything between 70 and 180 feet below the surface. We got across this desert zone, I think, largely owing to our accurate geological knowledge of the ground, and also to our extreme good fortune in finding many of the German installations repairable. To take 300,000 men and 100,000 horses across an area like that is a feat, I think, which has seldom been equalled. Of course we depended largely upon boring. During the advance, and in face of the enemy, we made thirteen bores about 250–300 feet in depth; in some cases the boring plants were in line with the field guns, and the crews, unfortunately, in two cases were knocked out by shell fire. The bores were most successful, and as a result the Army was well supplied with water. That is only one instance; there are many others in which we depended upon the geological knowledge of these two officers. I leave General Harvey to deal with subjects connected with mining, for which he was responsible. In regard to inundations, water-supply, collec-

tion of road metal, the manufacture of concrete and other things, we depended largely upon geological knowledge, and I hope that in the future, when our intelligence records about countries are prepared at the War Office, there will be a geological branch of the Intelligence which will be able to deal adequately with this side of engineering intelligence.

Brigadier-General R. N. HARVEY: Although mining had been going on for nine months before I took over the appointment of Inspector of Mines, I did not realize that geology had anything to do with military mining. We were not mining very deeply in those days, and naturally if we came to a wet place, if the Germans were mining we continued, and if it was wet we pumped; but there was no geological science so far as that was concerned. It was when we came to deep mining that its importance was obvious, and at the time of the advent of the Australian Mining Corps and Colonel David in March 1916 I was actually Inspector of Mines, and we were just beginning to think of mining deep, that is, mining between the depths of 75 and 120 feet. Naturally it was important to know what we were going to meet below. Just after Colonel David came he got busy at once on the 1st Army front and put them right on many matters to do with the level of the water in chalk, and I began to believe that there was something of value in geological information. That belief culminated when Colonel David fell down a well and very nearly killed himself. Then I was determined that the geological information should not disappear with Colonel David, and I called him back to G.H.Q., where I was, to keep him there. That, I think, shows that I realized the value of geology. I worked with Colonel David for two years off and on, and he was extraordinarily valuable. Captain King said that Colonel David made a point of working with him, and I can vouch for this, for he always said, "I should like to take Captain King with me," when I was sending him out on a job. That is why Captain King had such an intimate knowledge of the working of my office. The two of them used to work together, and they were both extremely valuable to me. With regard to the borings on the river at Nieuport, it was from the geological information got from the borings conducted by the Australians that the idea of making a tunnel under the River Yser developed, and consequently a special mission came home to see whether it was possible to make a tunnel under that river. Although it may not seem so, the information we got about dug-outs is extremely important. Before all operations of 1917 we had to make an enormous number of dug-outs for the special protection of Headquarters, and it was due to the borings systematically conducted by the geologists that we got to know where we could make them. There was one particular case in which we wanted to make a dug-out in a hill; the dug-out consisted of two long tunnels connected by a gallery under the hill. We got one in perfectly dry; the other ran wet almost at once. It was very near to the 7th, and it was absolutely necessary that these Divisional Headquarters should be finished by that date. I happened to be inspecting in that area when the miners met the wet clay about 20 feet in. I sent out Colonel David next day, and he came back and said, "You have begun on the wrong side of a fault; if you go 100 feet to the left of the first tunnel you will get through all right. We followed his advice and completed the dug-out without any further trouble. That was of absolutely practical value and made the difference between being able to make the dug-out for this particular Divisional Headquarters or not. The ground was so wet that it was impossible to make dug-outs near the surface. By a systematic programme of boring Colonel David found that there were areas in which there was sufficient depth of clay to make dug-outs between a top layer of wet clay

and the greensands. This clay sandwich was exploited, and it was entirely due to the information supplied by Colonel David and his party that we were able to provide safe underground accommodation for the troops of that area. The saving of mines from flooding by foretelling the rise of water-level in chalk was an actual fact. Before we had this information we lost a very important system of mines for six weeks while they were flooded, and only made the position good again from the fact that the Germans found out that we were not working and they also stopped. But we found afterwards that their mines were about 15 feet higher than ours, and above the water, while we were in it. I think if they had assumed a definite mining offensive here, they must have blown us off the important position we were holding.

I think I have said enough to show that from the military miner's point of view geological advisers must always be indispensable during war.

Brigadier-General J. E. EDMONDS (late Deputy Engineer-in-Chief B.E.F.): It was only towards the close of the war that the two geological offices were amalgamated and I was detailed to take military charge of them. I think it is the first war in which there have been geologists engaged on both sides. I believe Napoleon took geologists to Egypt, but I never heard of him taking them on the second campaign. We had very little information, geological or otherwise, when we started in August 1914. We did not know where we were going; even our maps were put up in sealed boxes, and we were not allowed to open them till we were on the seas, and, as you saw from Lord French's articles, it was not till August 5 that the higher authorities decided where the B.E.F. should go. Naturally, when we got to France we expected to be given information there. When we arrived in Flanders the Engineer-in-Chief sent me to General Foch's Headquarters (he was commanding in the north at Cassel), but the French appeared to have little or no geological information. However, eventually, as you have heard, we gradually collected it for ourselves. It was not till the middle of 1915 that we discovered the Germans were using geologists, and the fine establishment they had was always the envy of Colonel David and of Captain King. Whenever we captured a paper about geologists they used to bring it in and say, "The Germans have twenty geologists." However, there is another side to the question, and there is a little story I think ought to go on record. When our people got into Lille Colonel David told me there was a most eminent professor of geology there, Professor Barrois, and that we ought to go and see him. I did not think much of the idea, but we were all so fond of Colonel David that I let him have a car, and he went to Lille and saw Professor Barrois, who told him that the Germans had used his lecture-halls and museum the whole time they were there for geological purposes, and that they had from twenty to thirty geologists on the Western front. The morning after General Harvey blew up Messines ridge there was trouble among the professors. A German general appeared at the museum with his staff; the geologists were brought before him; they were called to attention, and he cursed them up hill and down dale, because they had not informed him that General Harvey was mining underneath the German mine system, and had led him to believe that mining below it was impossible. He ordered all the geologists over forty to be sent back to Berlin, and those under forty to the front. The moral perhaps is that it is better to employ two first-class geologists like our own than twenty second-class or German ones.

It may be worth recalling that the study of geology in the Army appears to have gradually dropped out. A certain knowledge is desirable for staff officers in order that they may use their specialists to best advantage. When

I was a young officer at the S.M.C., Chatham, Prof. Green of Oxford came every year and gave a course of lectures, and took us on a geological tour for ten days. This custom must have ceased soon afterwards, as General Harvey tells me it did not exist in his time. When I was at the Staff College, Colonel Cooper King gave lectures on military geology, and took us walks particularly to show us how geology affected water-supply. He died a few years after, and had no successor at Camberley. It is to be hoped that the study of elementary practical geology in the Army will be revived.

Colonel E. P. BROOKER : I would only like to add my testimony to that of others in regard to the great help we have had from the geologists in France. Notwithstanding what General Edmonds says, I hope we shall have sufficient geologists if we ever have a great war again, and we all hope that will not happen. Our two geologists were overworked. Captain King is very modest ; he has not told you the amount of work he had to do in visiting all parts of the front. He was always most willing to help, and gave everybody the utmost satisfaction.

Dr. J. W. EVANS : Having heard Colonel David's account at the Geological Society of the work of the geologists attached to the British forces on the Flanders front, and remembering the terms in which he spoke of Captain King, I welcomed the opportunity of learning further particulars this afternoon from Captain King himself. I am very glad to hear that the war has caused the Army authorities to appreciate the importance of geology and geologists in military operations, and that they only regret that they did not have them sooner, and that they had so few of them. I was very interested in Captain King's account of the relation of the water-level to the rainfall and evaporation. Most of us in this country are well acquainted with the fact that the rain that falls in the summer has very little influence upon the water-level in the chalk. I am sorry that Mr. Whitaker is not here, because it is a subject in which he is very interested. I have heard him say that it does not matter how much rain falls in the summer, the water in the chalk will never be raised sufficiently for the "bournes" (or "nailbournes") to appear in certain of the usually dry valleys in the chalk, whereas a much smaller amount of rain, as long as it is more than the average, in winter-time, when the evaporation is less, will have that result. It is for that reason these streams are sometimes called winter bournes.

Captain King's account of the operations on the front was specially interesting, because the geology there is to a large extent a repetition of that which we have in this country, so that those of us who were not young enough to have been present at the Flanders front were able to follow him in every detail of what he had to tell us.

The CHAIRMAN : Captain King has put a great deal before us, but a small part only of the work that he and Colonel David did out at the Front. Until September 1918, Colonel David, Lieut. Loftus Hills, and Captain King were our only geologists on the Western Front, and I was pleased to hear the comments that have been made during the discussion on that fact. Another point that struck me as being inexpedient, was that Colonel David and Captain King were under different authorities. Now jealousy, departmental or otherwise, finds no place in Colonel David's temperament, but it might have been different. Moreover, it appears to have been a mere chance that their offices were close together. The organization which put them under different authorities was so far faulty. Again, a result of the failure to provide sufficiently soon for geological advice was the blowing up by the enemy of at least one crater, which was, I believe, an exceedingly serious catastrophe.

Also I understand that a system of mining of the first importance was started on wrong lines for the same reason, but that geological advice was available just in time to get it put right. That is a happy-go-lucky way of proceeding. It was not the fact that geologists were non-existent that prevented their being available at the front, for several of the Geological Survey staff were serving as privates, and there were others in this country who were anxious to go out, but their applications for employment as geologists were set aside. I discussed this subject with Colonel David, and eventually, while he was on his way back to Australia and passing through the Suez Canal, he wrote the following memorandum and posted it to me:—

(1) For some years before the War the German geologists had impressed on the military authorities the importance of having geologists attached to the Military Staffs.

(2) Although there was some delay in the appointment of many geologists to the German Armies, we find that in 1915 and 1916 several were at work at or close to the front, and towards the beginning of 1917 there appears to have been, according to Prof. Barrois of Lille, a definite Geological Establishment, and some thirty professional geologists were systematically employed by the German Army Staff.

(3) As a result of being strong on the geological side the Germans were at an advantage in many ways. Thus,

(*a*) They did us much damage at Givenchy lez la Bassée by military mining on exactly the right geological horizon, whereas we were mining on a wrong horizon owing to neglecting the study of the geological conditions.

(*b*) In the Loos salient the same position recurred. The German geologists had prepared an accurately contoured map showing the maximum underground water-level in the chalk, and so were able to continue their military mining in that salient in places where out-tunnelling companies through ignorance of the geological conditions had been drowned out.

(*c*) In the matter of water-supply in the German Armies the boring for water was always done under geological advice instead of by the trial-and-error method so common in the British Armies, during the first two years of the war, and so wasteful of labour and life. (In the last two years of the war this was the work of the only three British geologists available for all the armies. Far more efficient work could have been done with a larger staff.)

(4) With fewer armies in the field the Americans appointed 17 geologists, as compared with our total of three for both our G.H.Q. and for our five armies taken together.

(5) There should in future, in my opinion, be at least three geologists attached to G.H.Q. on staff of Engineer-in-Chief: (*a*) For water-supply; (*b*) for field positions (dug-outs, subways, etc.); (*c*) for mining of raw materials, road metal, concrete material, etc.; and one geologist at least attached to the staff of each Chief Engineer of Armies.

It would pay, in my opinion, to go farther and have a geologist attached to the C.E. of every Army Corps.

Colonel David's scheme is what you may call a war-time organization. I hope that it is only necessary for us now to consider what should be the peace organization. I think you will agree that it will be regrettable if the training

of these men and the information they have gathered are to be lost and not made use of for the future. It is not only that they have got together a lot of documentary evidence and constructed maps of inestimable value, but that they have gained their experience. The question is how the best possible use of this experience can be made. In the ordinary course of events I believe that Captain King, if he remains in the Territorials, will go out for a fortnight's training every year and perhaps be engaged in ordinary manœuvres. Surely it would be possible and better for such men to be used for the training of a small staff in this special work. There are many parts of England that are suitable for the purpose and would provide training in the kind of work that has been going on at the front during this war. The experiences of these men should be passed on to the next generation, and whatever and whenever the next war may be, let us not be unprepared, either in the training or organization of a geological staff. There are many branches of the work of military map-making in which geological training is required, as, for example, to take the subject of water only, in the preparation of water-supply maps, that is to say, maps showing areas of good or indifferent water-supply, both as regards quantity and quality, and areas of no water-supply ; maps dealing with underground water, such as have been prepared at the front, showing the water-table ; and maps, documents, or reports dealing with the question of seasonal variations in the water-table. It does not follow that Colonel David's conclusions with regard to the seasonal variations on parts of the Western Front will apply to all other geological formations or to all parts of England of similar geological character, but at any rate a study of the variations in the water-table should form a part of the training, as well as the preparation of geological maps and sections showing water-bearing strata.

The point I wish to emphasize is that we should—and I hope the War Office will take the matter up—make use of the experience and the training which has been obtained by our geologists in the last war for preparing a proper geological organization.

Captain KING : I do not think I have very many remarks to make, but I should like to thank you all, particularly my late chiefs out in France, for the very kind way in which you have spoken, and also, of course, I very much want to emphasize the great pleasure it has always been to me to work with Colonel David. Colonel David was Colonel David ; had he been some one of a different type my position might have been a very difficult one, because our work in some cases did overlap a certain amount. Colonel David was connected with the Australian Electrical Mechanical Company which was under General Harvey, but they had a Water-boring Section with them ; all the other Boring Sections were under the armies ; thus the geologist who dealt with bores made by the Australians came under the Inspector of Mines, whilst he who dealt with those made by the Army Water-boring Sections was under the Engineer-in-Chief, and so there was some overlap at times, but with Colonel David it made no difference. He even used to ask me for suggestions, which was quite unnecessary on his part, and he would always give me any help it was possible to give.

Motors were always very scarce, and it is not any good having geologists unless they have transport. It is a very old subject, and I can see General Edmonds smiling about this. But it is absolutely useless having a staff of people to do the work and not having any facilities for them to get out and see the ground. As it was, very often we did not see as much of the ground as we would have liked, and it was, I suppose, the same with every one. It is, however,

absolutely essential in this case, and it is no good having fifteen geologists unless they have some method of getting about and doing the work on the ground themselves. They must see the ground and be in close touch with the men who are going to use any maps or reports which they make. And then it is also important that the geologists who are doing this work should have tact. It is no good rubbing people up the wrong way and telling them they do not know anything about the subject, because every one thinks that he knows a certain amount about everything.

I was not at the Geological Society meeting, but from what I have heard I think it is just as well I was not there in view of the things Colonel David said about me.

The CHAIRMAN: May I, before we separate, move a hearty vote of thanks to Captain King for his paper?

IRRIGATION IN THE UNITED STATES

R. H. Whitbeck, Professor of Geography, University of Wisconsin, Madison

APPROXIMATELY 500,000,000 acres in the western half of the United States are very sparsely peopled, and normally produce almost no crops because of a single unfavourable feature in the structure of North America—the position of its main mountain axis on the windward side of the continent; in this particular, resembling Australia and differing from Europe. Because of this unfavourable position of its great cordillera, an area ten times the size of the British Isles lacks one thing essential to the production of food, namely, abundant water.

Owing to the fact that our planet has an enormous allotment of water, vegetation in its evolution upon the Earth has acquired exceeding bibulous habits. Most forms do not know how to function effectively unless they are supplied with a large amount of water. The average crop-plant transpires 450 times the weight of its own dry substance during its growth.* A bushel of wheat or corn in a humid climate requires for its production about 250,000 pounds of water; and the cereal and meat food for the average American requires the services of 4000 tons of soil water annually.* This means that the air currents must bring to a region from 5000 to 10,000 tons of rain yearly for every person whom that region feeds. The United States Reclamation Service plans to supply for irrigation 5000 to 6000 tons of water for each individual on the irrigated lands. On the basis of the available water falling upon its agricultural lands, McGee estimated that the United States could feed a population of one thousand millions.*

In the arid south-western part of the United States the Indians

* McGee, W. J., *Science*, N.S. 34, 816.

practised irrigation in a crude way centuries before the white man came. The Spanish settlers of this region, especially in southern California, employed irrigation; and the English rice-growers of Carolina and Georgia began the practice as early as 1700. The first Mormon colony in Utah, in 1847, found irrigation essential to agriculture, and the reports of its success were spread by the gold-seekers, many of whom passed through the colony on their way to California. With the completion of the Union Pacific–Central Pacific railway line to the Pacific coast in 1869,

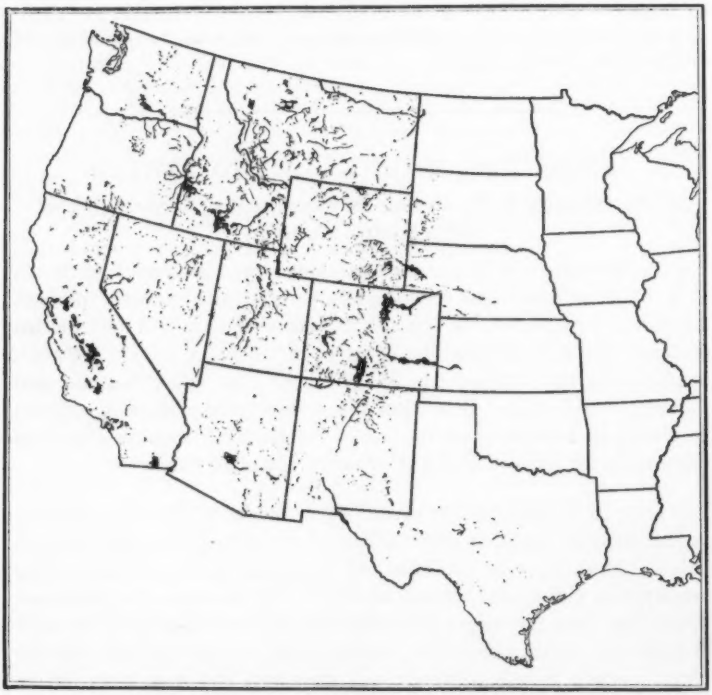


FIG. 1.—IRRIGATED AREAS IN THE UNITED STATES, 1909

settlers flowed into the Far West, and irrigation on a small scale began in nearly all of the arid territories. By 1889, 54,000 farms, having a total area of 3,600,000 acres, were under irrigation,* but none of the areas were large, and the construction work was mostly of a temporary character. The undertakings were carried out and managed by the settlers themselves or by groups of settlers working co-operatively. Even down to 1910 half of the land under irrigation obtained water by means of individual and partnership enterprises. It is to be remembered that all of this western

* U.S. Census of 1910, 'Irrigation,' vol. 5, pp. 833–876.

FIG. 2.—PART OF A GOVERNMENT ROAD 70 MILES LONG FROM PHŒNIX TO THE ROOSEVELT DAM, ARIZONA, USED FOR CONVEYING MATERIALS REQUIRED IN THE CONSTRUCTION OF THE DAM

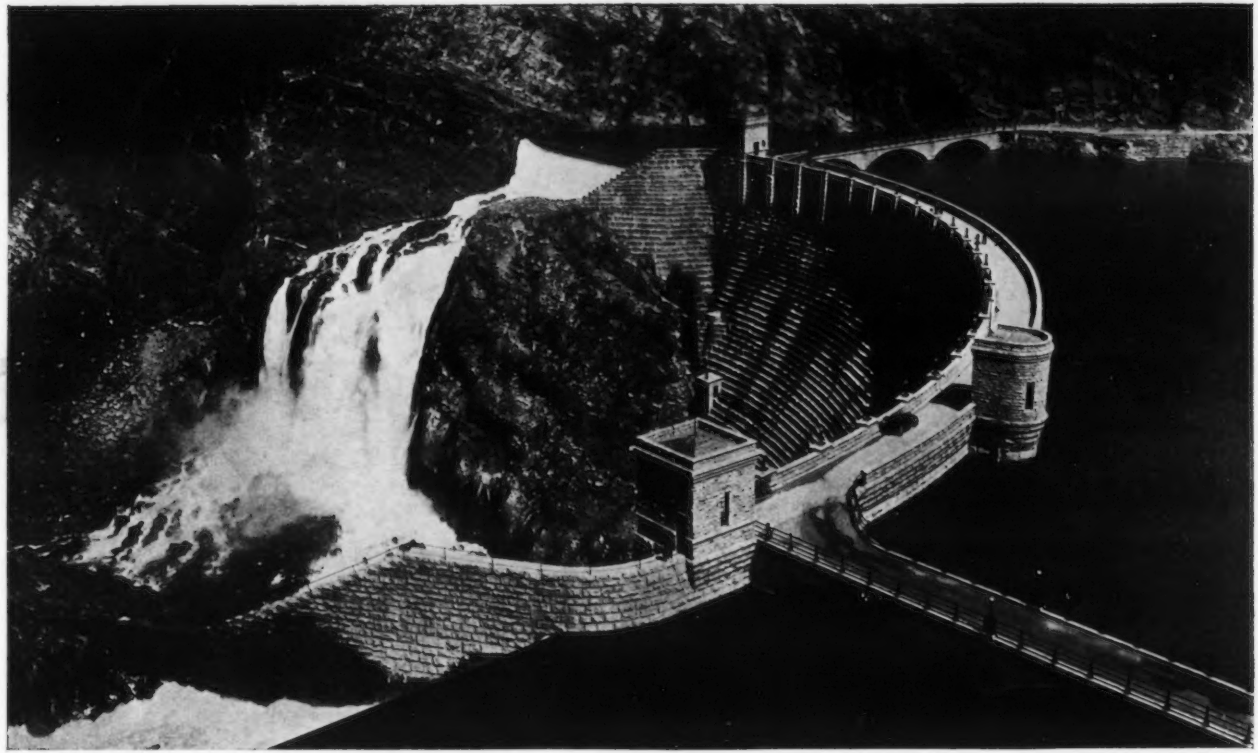


FIG. 3.—THE ROOSEVELT DAM IN ARIZONA BELONGING TO THE SALT RIVER IRRIGATION PROJECT

land had belonged to the U.S. Government; but farms were obtained by settlers on exceedingly liberal terms—terms that virtually amounted to a gift.

The first settlers had their choice of land, and naturally selected that which, if it required irrigation, could be cheaply and easily irrigated. In many cases this required merely the throwing of a crude dam across a stream that came down from the mountains and flowed across an alluvial fan or flood plain whose soil needed only water to make it productive. In 1909 nearly half of the land then under irrigation belonged to these small individual or partnership undertakings, whose average cost amounted only to about seven dollars per acre of irrigated land.*

In many cases it was advantageous or necessary for a number of settlers to unite in a co-operative enterprise. In 1909 these co-operative undertakings supplied water to about one-third of the irrigated land, and represented a cost of about $13.00 per acre.* There were still other undertakings which, if accomplished, would require a large amount of capital; these were usually initiated by corporations which sold bonds to secure the needed money. These commercial enterprises were often over-capitalized, and were conducted more with a view to profit for the irrigation companies than for service to the farmers. In 1909 about one-tenth of the irrigated land was supplied with water by commercial companies.*

Four other methods of conducting irrigation enterprises have been devised, only one of which—the U.S. Reclamation projects—has had any considerable development. The other three are: (1) U.S. Indian Service enterprises; authorized by Congress, providing for the construction of irrigation works on Indian reservations by the U.S. Indian Service. (2) Carey Act enterprises; authorized by Congress, granting to each of the states in the arid region 1,000,000 acres of Government land on the condition that the State provide for its irrigation. (3) Irrigation districts; controlled by the water users, and organized under State laws. These three methods combined had not resulted in the irrigation of a million acres of land by 1909.

TABLE I.—SOURCE OF WATER USED FOR IRRIGATION, 1909.

	Acres.
Water supplied from streams (94·1 per cent.):	
By gravity	12,763,797
By pumping	157,775
Water supplied from wells† (3·3 per cent.):	
Flowing	144,400
By pumping	307,496
Water supplied directly from reservoirs	98,193
Water supplied from lakes	70,638
Water supplied from springs (1·4 per cent.)	196,186
Total	13,738,485‡

* U.S. Census of 1910, 'Irrigation,' vol. 5, pp. 833-876.

† Over 75 per cent. of these are in California.

‡ Of this, 477,625 acres were irrigated with pumped water.

FIG. 3.—THE ROOSEVELT DAM IN ARIZONA BELONGING TO THE SALT RIVER IRRIGATION PROJECT

TABLE II.—TOTAL ACREAGE AND PER CENT. OF ACREAGE IRRIGATED BY VARIOUS CLASSES OF ENTERPRISES IN 1909.*

Class of enterprise.	*Total acres irrigated.*	*Per cent.*
ALL CLASSES	13,738,485 ...	100·0
U.S. Reclamation Service	395,646 ...	2 9
U.S. Indian Service	172,912 ...	1·3
Carey Act enterprises	288,553 ...	2·1
Irrigation districts	528,642 ...	3·8
Co-operative enterprises	4,643,539 ...	33·8
Individual and partnership enterprises	6,257,387 ...	45·5
Commercial enterprises	1,451,806 ...	10·6

In 1902 the so-called Reclamation Act was passed by Congress. This Act provided for the construction of irrigation works by the U.S. Government with money received from the sale of public lands. On the whole, the practice of irrigation farming in the arid West had been encouraging. Many people in these states and outside believed that the U.S. Government might very properly use the proceeds derived from the sale of public lands for the construction of extensive and permanent irrigation works—enterprises in which the cost was larger than could readily be met by individual or corporate effort. The Act provided that the water users were to pay back the cost of the works to the Government in ten annual instalments. This was later (1913) extended to twenty annual payments. The earlier private and corporate irrigation works had been inexpensively constructed, and many of them fell into disrepair, resulting in unsatisfactory service. Sometimes the dams were washed out by a flood, and the season's crops were a partial or total failure. In other cases the storage capacity of the reservoirs was insufficient, and water ran short before the crops matured. Others of these enterprises, however, have been thoroughly successful and are still in operation.

When the Reclamation Act of 1902 was passed, it was believed that with the financial backing of the Government, reservoirs of large size capable of supplying water to extensive areas at moderate cost could be constructed; thus, in 1902, began the great undertakings of the U.S. Reclamation Service. The following tables III. and IV. present certain statistics for the year 1902, the last year before the large Government project was begun.

TABLE III.—STATISTICS OF IRRIGATION IN THE UNITED STATES OF AMERICA IN 1902.

	Total.	*From streams.*	*From springs.*	*From wells.*
Number of farms irrigated	134,036	121,461	2531	10,044
Number of acres irrigated	9,487,077	9,111,175	107,424	268,478
Construction cost	$93,320,452	—	—	—
Construction cost per acre irrigated ...	$9.84	$9.31	$5.23	29.40

* U.S. Census of 1910.

TABLE IV.—NUMBER OF ACRES UNDER IRRIGATION BY STATES IN 1902.

Arizona	247,250	New Mexico	254,945
California	1,708,720	Oregon	439,981
Colorado	1,754,761	Utah	713,621
Idaho	713,595	Washington	154,962
Montana	1,140,694	Wyoming	773,111
Nevada	570,001		
		Total in arid states	8,471,641

The U.S. Reclamation bill met with determined opposition from a minority in Congress who opposed the Government's undertaking irrigation work and devoting thereto the public money. By some the plan was looked upon as a species of "pork barrel" legislation designed to benefit private interests in one section of the country. But in their party platforms of the preceding presidential election, both of the great political parties had pledged themselves to such a measure; President Roosevelt energetically supported it, and it was passed. The more enthusiastic advocates of the measure predicted a rush of home-seekers into the west, to be followed by unprecedented prosperity. The Secretary of the Interior, Mr. Hitchcock, went on record as follows: "The moment the Government throws down the desert barriers, or announces its purpose of so doing by making possible the obtaining of water, there will be an eager rush on the part of home-seekers. With the requirement of actual settlement and cultivation, to be followed by the payment of the cost of storing the water, the speculative element will be eliminated, leaving the ground free to *bonâ fide* settlers." "It (the irrigated land) will tend to relieve the congestion of our great centres of population, creating opportunities which would go far to allay social discontent."

The United States paid France only $15,000,000 for the vast territory west of the Mississippi known as Louisiana (about three cents an acre). It has already expended nearly this amount on one single irrigation project, the Salt River project in Arizona.

The conditions surrounding the building of irrigation works in the mountainous lands of the United States differ widely from those which faced the English engineers in Egypt or in India. The valleys of the Ganges and Nile are open plains, densely peopled. The great irrigation works there were extensions and improvements of very old systems. They were constructed to meet the pressing necessities of already over-populated lands. In the case of Egypt, one river, whose regimen was well known, was concerned. In India there was greater variety than in Egypt; but in the western United States, no two of the thirty great projects were alike; and in practically every one there was at least one major engineering problem for whose solution there was scarcely a precedent.

The thirty projects (Fig. 4) are scattered over an area nearly as large as Europe outside of Russia. Many of them are among mountains where there were few people, where labour was exceedingly hard to secure and

to retain; where all provisions, construction materials, machinery, and general supplies had to be transported long distances—in some cases over mountain roads 20 to 50 miles in length (Fig. 2). The northern projects are in a climate where the temperature falls to 45° Fahr. below zero, while four of the southern projects are in the most intensely hot portions of North America.

The great variety of engineering problems and the methods employed in their solution may be illustrated from a few of the projects. In North

FIG. 4.—SITES OF IRRIGATION PROJECTS OF THE U.S. RECLAMATION SERVICE

Dakota, in the Williston unit the engineers found it impossible to secure water from the Missouri River by gravity methods, but lignite beds existed on Government land a few miles away. Here they installed a modern electric generating plant, using the lignite for fuel, and sent the current to a pumping plant installed on a barge anchored in the river, whence the water is pumped into a reservoir and is distributed by gravity to the land. Government coal of a quality too poor to ship was to irrigate 30,000 acres of previously waste land. This project has not, however, proved very successful.

FIG. 5.—ONE END OF THE 6-MILE GUNNISON TUNNEL BY MEANS OF WHICH 140,000 ACRES IN COLORADO ARE IRRIGATED

An idea of the scale is given by the three men standing above the tunnel.

FIG. 6.—METHOD OF DISTRIBUTING WATER FOR GRAIN CROPS. GRAND VALLEY PROJECT, COLORADO

FIG. 7.—SAGE-BRUSH DESERT OF EASTERN WASHINGTON. WHEN CLEARED AND IRRIGATED, THIS BECOMES HIGH-GRADE ORCHARD LAND

FIG. 8.—IRRIGATED ORCHARDS IN THE GRAND VALLEY, COLORADO. LAND FORMERLY A DESERT

In Western Colorado is the Uncompahgre Valley, with a broad alluvial plain traversed by a small stream. Some miles away in a parallel valley is the larger Gunnison River flowing in a canyon. One valley had land without water and the other water without land. The engineers drove a tunnel 6 miles long through a mountain range and brought the water of the Gunnison to the valley of the Uncompahgre and it is irrigating 140,000 acres (Fig. 5).

In the Yuma project in California–Arizona, the main canal has to be on the California side of the river, where there is less land to irrigate than on the Arizona side. An enormous inverted siphon passing under the river has been constructed, and the surplus water is carried to the east side, where it is distributed.

In the construction of dams for the reservoirs, a wide range of problems was presented. In several of the projects dams were built across deep and relatively narrow mountain gorges where the dam had to be very high but could be firmly anchored at the bottom and sides in solid rock. The famous Roosevelt dam in Arizona is solid masonry 280 feet high, 235 feet long on the bottom and 1125 feet long on top (Fig. 3). So great is the pressure of the impounded water that the dam is 180 feet thick at the base. A roadway on top is wide enough for three automobiles to travel abreast.

The Arrowrock dam in Idaho is 349 feet high, and the Sun River dam in Montana is 329 feet high; the Elephant Butte dam, in New Mexico, 318 feet; and the Shoshone dam in Wyoming, 328 feet. Other dams have been built in broad, open valleys where great length and thickness but small height were requisite. The Hondo dam in New Mexico is only 25 feet high, but has a crest length of over 3 miles. The Nelson Reservoir dam in Montana is 39 feet high and 4 miles long.

No two undertakings were alike. The ingenuity and resourcefulness of the engineers were tested anew with every project. No case illustrates this better than the Salt River project in Arizona. The topography of the region led to the adoption of a dam site 60–70 miles from the land which was to be irrigated. The nearest town of any size was 70 miles away, and the nearest railway 40 miles. The site selected for the dam was in almost inaccessible mountains (Figs. 2 and 3). From the railroad to this site a road had to be constructed, miles of it cut into the precipitous face of the mountains (Fig. 2). This road alone cost a half-million dollars. The expense of getting timber and cement to this remote region, involving a waggon haul of 40 miles, would have been prohibitive. Moreover, labourers could not be induced to go there to work. Yet the building of the dam required a vast quantity of materials, a great number of workmen, and a large amount of mechanical power. The engineers decided to develop hydro-electric power at the dam site, and they built a power canal 15 miles long costing a million and a half dollars, installed a power plant, and produced their power on the spot. They erected a cement mill, quarried the rock for making the cement, and manufactured their entire

requirement, 300,000 barrels, at the dam site. They built a waggon road 20 miles through the mountains to Government forests, cut their timber, erected a saw-mill, and sawed the necessary lumber. About the only inhabitants of the region were half-civilized Apache Indians who despise manual labour, yet the Government officials actually induced hundreds of them to don overalls and wield the pick and shovel for daily wages. In fact, the major part of the unskilled labour was performed by these red men.

So difficult was it to secure food supplies that Government employees raised a considerable part of the food needed for the men. Thus it was that power, cement, timber, labour, and food were wrung from the mountains and the desert, and the great dam was finished. It stores enough water to irrigate the dependent lands (200,000 acres) for two years, even if no rain fell in its catchment basin in that time. This project has 800 miles of canals; it cost over $12,000,000 to construct; the power plant now sells electric power to the value of a half-million dollars a year, and a large part of the cost of the project may be paid for from this income.

Such triumphs over well-nigh insuperable difficulties have made a strong appeal to the imagination and to the pride of the whole nation, and this is not the least of the returns upon the hundred million dollars and more already expended on the U.S. Reclamation projects. Unfortunately, not all of them are proving so successful as this one in the Salt River Valley of Arizona.

The problems are not all solved when the reservoir and distributing system are completed and water is delivered to the land. The desert soil is porous and the water readily percolates through it. In a few years an excess of ground water accumulates and spreads to the lower land, water-logging it and possibly ruining it for crops. The owners of this land demand relief, and the Government must install a drainage system and possibly a pumping system to get rid of the surplus water. Nearly every project is presenting this problem in a greater or lesser degree, and large sums of money are required for undoing the injury. In the Boise project in Idaho, for example, 150 miles of drainage ditches costing $700,000 have already been dug to prevent water-logging of the land. This difficulty promises to increase, and the additional cost due to drainage work must be assessed against the land which is benefited. In nearly every project the cost of construction has already far exceeded the original estimates, and still further costs, due to drainage works, are causing no little dissatisfaction among the water users.

The uncertainty regarding the final costs to be paid by the water users is deterring settlers from taking up the lands, and nearly all of the projects have a large amount of land to which water can be supplied but upon which there are no settlers. Unlike Egypt and India, there is no pressure

of population in the United States. There is much unused farm land in nearly every state in the Union, and home-seekers do not need to go to the irrigated lands to find farm homes. Instead of the predicted rush to secure irrigated lands the Reclamation Service has had to carry on a continuous publicity campaign to persuade people to go to them, and this with only partial success.

Alfalfa hay is the largest crop grown under the U.S. Reclamation projects, occupying 40 per cent. of the area and yielding 36 per cent. of the value of all crops. All cereals together occupy 24 per cent. of the ground and yield only 14 per cent. of the value. Cotton yields 11·6 per cent. and fruit 8·4 per cent. of the total value of all crops. The average value of crops, $58 per acre, is more than double the value in 1913, owing to war prices. This value of crops per acre is somewhat higher than the average obtained from general farm land in the United States in 1917, though probably not more than five to eight dollars higher.

It is fully established that it costs more to produce crops on our irrigated land than it does on good land under rainfall. The U.S. Reclamation Service found (before the war) that the average 40-acre irrigated farm involves an invested cost of money and labour of about $10,000. The Department of Agriculture studied sixty-nine farms (average of 50 acres each) in Utah—old and established enterprises—and found that the average investment was about $175 per acre, and the gross receipts a little under $1500 a year for each farm. Cash expenses averaged about $600 per farm, leaving the farmer $900 for his own work and his return on a $9000 investment.

Assuming these figures to be representative, it seems clear that general farming under irrigation offers the average farmer little more than a living for his labour. As in other occupations, the good manager succeeds and the poor manager fails. There are, however, conspicuous cases of success, especially among the fruit growers. A very large part of the splendid fruit grown in California is grown under irrigation, and many of these fruit growers have become wealthy. Any quantity of the most luscious fruit can be grown in this sunny western climate. The production can be increased enormously as fast as the market will take it. Unfortunately for the fruit growers, over 80 per cent. of the population of the United States is in the East, while the most productive fruit lands are in the Far West. This necessitates a long and expensive railroad haul which operates unfavourably in two directions: it cuts down the price the grower can secure and also raises the price to the consumer. The latter fact tends to restrict the consumption of fruit, and the western fruit grower often sees quantities of the finest fruit rotting on the ground because there is no profit in marketing it.

In the older fruit-raising districts, especially in California, a great deal

of fruit is preserved in tins, or is dried, thus avoiding the waste of the fruit which is not marketed. California is also developing on a large scale the production of fruits and nuts which are not quickly perishable and can be shipped by less expensive modes of transportation than the fast fruit trains of specially constructed refrigerator cars. For example, California produces from 25 to 30 million pounds of figs, nearly as many olives, 30 to 40 million pounds of almonds, pecans, English walnuts, etc.

Most of the irrigation in California is under private control. It has been in progress more than fifty years; a fund of experience has been accumulated, the unsuccessful growers have been largely weeded out, and irrigation is firmly established. There is no question of its success here. The Salt River project in Arizona and the Yakima project in Washington appear to have passed the experimental stage and to be on their way to complete success. This is not yet true of the majority of the newer projects, however.

If the question is asked, Has Irrigation in the United States been a success? the answer is neither Yes nor No. It has been an unquestionable success in many of the 55,000 separate enterprises. It has been a reasonable success in a still larger number, and it has also been a financial failure in many. No reliable figures are available, for no record has been made of the cases of failure. The boom given to irrigation in general by the passing of the U.S. Reclamation Act of 1902, and an enormous amount of advertising, led to the undertaking of many large corporate enterprises whose stocks and bonds were widely sold between 1902 and 1912. Many of these enterprises failed, and of those that are still operating "few if any are paying any return on the capital invested." *

In nearly every one of the U.S. Reclamation Service projects there are large areas of land which the Government is prepared to irrigate, but people are reluctant to take the land and assume the charges assessed against it to pay the cost of building the irrigation works. On several of the projects more than half of the irrigable land is unused. Had the Reclamation Service projects been obliged to finance their cost as private projects are financed, all would have gone into bankruptcy. All of the money which the Government has been able to collect from water users would pay but a fraction of the interest charge alone. The majority of the projects are not paying to the Government operating and maintenance costs. Were the Government officials to insist rigidly upon compliance with laws and contracts, large numbers of irrigation farmers would be ruined. The Government has no choice but to be lenient or see many of its undertakings fail. These irrigation works have been very expensively constructed. Their cost has been far greater than was predicted when the Reclamation law was passed. The result is that the lands are not in

* Teele, Ray Palmer, 'Irrigation in the United States,' p. 222.

pressing demand, and at the present rate of taking up these lands by settlers, ten years will elapse before the irrigable lands already awaiting occupancy are completely occupied. The Reclamation Service has already expended about $100,000,000 received from the sale of public lands; it has borrowed $20,000,000 more, and may shortly be compelled to seek further Government aid to maintain and complete the projects already under way.

To many Americans, it appears that the Government entered upon its extensive irrigation enterprises too soon and on too costly a scale. Millions of acres of farm lands in the humid part of the United States are unused; millions more are producing but a fraction of their possibilities. There was no lack of good land that required no irrigation and would produce nearly as much as the irrigated land after great sums had been expended, merely to bring water to it. This irrigation experiment may cost the U.S. Treasury from a hundred million to two hundred million dollars, but it will not all be lost; a good deal of benefit will come from the undertakings. Besides, two hundred million dollars nowadays may scarcely seem worth worrying about!

ON THE POSSIBLE PROLONGATION OF THE HIMALAYAN AXIS BEYOND THE DIHANG

F. Kingdon Ward

THE marked resemblance between the Himalayan flora * and that of Western China might be due to a former direct geographical connection between the eastern Himalaya and the mountain system reaching out across China from the Tibetan plateau to the maritime plains (forming the watershed between the Yellow River and the Yangtze). It has therefore appeared to me worth while to investigate the following points:

(1) Do any vestiges of such a connection still remain amongst the parallel ranges, trending north-west to south-east, which intervene between the eastern end of the Himalaya and the western end of the Tsin-ling?

(2) Can any such direct connection be shown, by geographical and geological exploration alone, to have existed at some period?

(3) In the event of no direct proof of former connection being forthcoming, can it be shown that no such direct connection could indeed ever have existed—that the parallel ranges of Yun-nan and Szechwan are all, in fact, features of original structure?

Since in the latter event it would be necessary to discard the theory of a Sino-Himalayan connecting range and start afresh, I will first of all briefly state the *indirect* evidence in its favour. Secondly, I will consider the general distribution of the flora over this region, as at present known,

* Throughout this paper "flora" means "alpine flora" unless otherwise stated.

and its relationships. Thirdly, I will point out what results might be expected to follow, in the flora, from the breaching of such a range as the Sino-Himalayan, with the subsequent gradual uplift of a series of parallel ranges separated by deep and narrow gorges passing through the breach. The line of investigation to be pursued will then become clearer; in a complicated task of this nature, full of perplexing side issues, it will be necessary to keep strictly in view exactly what we are seeking.

The alpine flora of Western China shows a remarkable relationship with that of the eastern Himalaya,* while the sub-alpine and forest flora of China, as was pointed out by Prof. Asa Gray, finds its affinity with the flora of the eastern United States! This is an extraordinary fact which requires explanation.

The similarity between this Himalayan flora and that of the parallel ranges of Yun-nan is even more striking, and we must recognize the fact that the similarity is most marked in the case of high alpine plants which, generally speaking, have the poorest means of seed-dispersal and the least opportunity of being widely dispersed. Yet these plants have either been distributed by natural means under present conditions, with the mountain ranges as they now stand, or there was at some previous time direct communication for the plants to follow.

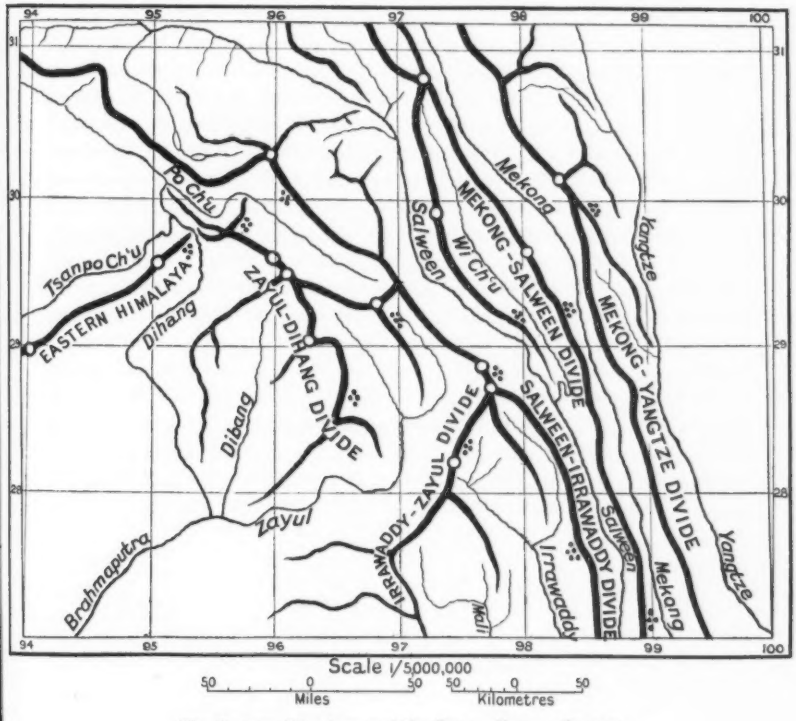
Now the flora of the eastern Himalaya could not cross the wide hot plains of Assam, the comparatively low mountain ranges to the east, and the hot valley of the Mali-kha, to reappear on the Salween–Irrawaddy divide. It must have travelled north-east, towards the knee bend of the Dihang, right round the head of the Assam valley, thence south-east, following the trend of the mountains separating the Zayul, Irrawaddy, and Salween rivers (see map). But it is as difficult to imagine an alpine flora crossing the gorges of the Dihang or upper Salween as it is to imagine it crossing the Assam plains.

Supposing, however, for the purposes of argument, that it had jumped the Dihang gorge, and achieved the great snowy range stretching down south-east between the Dihang and Zayul rivers; whence it might reach the mountainous divide between the Zayul and Salween rivers, from the southern ends of which rise the headwaters of the Irrawaddy. It is now stopped by the deep arid gorge of the Tibetan Salween, and beyond that again by the equally arid gorges of the Mekong and Yangtze rivers—it can indeed only have crossed these rivers much further north, that is, to the north-east of the Dihang bend. About this region we know little geographically, still less botanically; what we do know does not suggest a rich alpine flora; it would seem to be steppe country, though there are certainly forests.

If now we draw a line north-east from the Dihang bend, it will divide

* It was, I believe, Sir Joseph Hooker who first drew attention to the similarity between the alpine floras of the Himalaya and Western China.

this region into two climatic areas, more or less correctly. To the north-west lies plateau country, steppe, and desert; to the south-east forested mountains separated by deep arid gorges. The Himalayan flora could not have reached the trans-Himalayan ranges and the mountains of Yun-nan by crossing the Tsanpo, any more than it could have by crossing the Dihang. The northern slope of the Himalaya is much drier than the southern, and supports a somewhat different flora; there is the same difficulty about crossing the arid gorge; and north of the Tsan-po is the



The Eastern Himalaya and the Burma-Yunnan Ranges

dry Tibetan steppe-land. It would therefore appear that the only probable route by which the flora of the eastern Himalaya could reach western China would be, under present conditions, north-east of the Dihang bend, jumping the Dihang gorge.

It is profitless to speculate on the possibility of the flora having come down the Yun-nan ranges from the north-west and spread thence east and west to China and the Himalaya, for Tibet is now a desert, and we know nothing of what its flora may have been in the past. In order to escape

the same difficulty of crossing the river gorges, we should have to think of the whole of Tibet as far west as Ladak, and as far north as the Kuen Lun, supporting an alpine flora every trace of which has since disappeared.

Had the flora, on the other hand, travelled south-west from China to the Himalaya, we ought to find plants in the eastern Himalaya whose nearest relatives are Chinese, instead of plants on the Tsin-ling whose nearest relatives are Himalayan. The Tsin-ling flora, in fact, does not seem to have reached the Himalaya at all, and we are justified in assuming that the original home of this flora was the Himalaya. However we look at the matter, we see that to reach even as far east as the Szechwan mountains this flora has, under present conditions, to cross the Dihang, Salween, Mekong, and Yangtze gorges.

Yet this flora includes such genera as *Primula, Gentiana, Saxifraga, Isopyrum, Meconopsis, Arenaria, Diapensia, Lloydia, Aconitum, Cassiope, Corydalis, Cardamine, Polygonum, Androsace, Trollius, Pedicularis*, whose small seeds are simply shaken out of their capsules by the wind and scattered amongst the rocks. Moreover, many of them appear to retain their germinating power for only a short time, while for others the protection afforded by a snow blanket throughout the winter seems essential. One can conceive of no means by which such seeds could pass either directly from range to range, or gradually across the deep arid valleys intervening; though there is nothing to prevent them spreading many hundreds of miles along a mountain range. An alpine flora, in fact, marches slowly and compactly forward. The poverty of alpine floras on even the highest mountain ranges and peaks situated on islands proves that alpines are not widely distributed fortuitously. Yet identical or almost identical species of the above genera are found at least as far apart as the eastern Himalaya and the Mekong–Yangtze divide, as the following table shows:

Himalaya.	*Mekong–Yangtze Divide.*
Gentiana ornata	Gentiana sino-ornata
Primula sikkimensis	Primula pseudo-sikkimensis
Primula pusilla	Primula bella
Campanula colorata	Campanula colorata
Iris kumaonensis	Iris kumaonensis
Diapensia himalaica	Diapensia himalaica
Androsace chamaejasme	Androsace chamaejasme
Isopyrum grandiflorum	Isopyrum grandiflorum
Aconitum Hookeri	Aconitum Hookeri
Pinguicula alpina	Pinguicula alpina
Phlomis rotata	Phlomis rotata
Meconopsis racemosa	Meconopsis Wardii

On the other hand, plants whose seeds are capable of being transported long distances by wind are not more widely distributed than the genera mentioned. Species of *Clematis, Cremanthodium, Lactuca, Lilium, Rhodo-*

dendron, *Crepis*, *Saussurea*, are, generally speaking, quite different in the Himalaya and in Yun-nan; they even differ on different ranges in Yun-nan.

We might also expect to find plants with edible berries, eaten by birds, widely distributed on these ranges; but such is not the case. Species of *Lonicera*, *Euonymus*, *Cotoneaster*, *Actinidia*, *Viburnum* generally differ even on ranges as close to each other as are the Mekong–Yangtze and Salween–Irrawaddy divides.

Yet the alpine flora, which under present conditions has the least chance of crossing from range to range, is more closely related than is the forest flora. Moreover, if seeds could reach the Mekong–Yangtze divide, say, direct from the Himalaya in the past, there is no valid reason why they should not do so now, and continue to do so. Hence the flora should become more and more Himalayan in character west of the Yangtze, till by the time the Zayul–Dihang divide was reached, an entirely Himalayan flora should prevail. On this point it is impossible to speak with certainty, but considering the striking differences of flora between ranges so close as the Mekong–Yangtze and Mekong–Salween divides, it would not appear very probable that the flora of the Zayul–Dihang divide is completely, or even preponderantly, Himalayan. It is possible, however, that the differences in the flora of the Mekong–Yangtze and Mekong–Salween divides may be due to, or emphasized by, other causes than mere failure in the transference of seeds from range to range: of which more anon. Finally, there is the significant fact that some of the plants found in the arid Mekong and Yangtze valleys are Himalayan: *Amphicome arguta* and the Himalayan asphodel, for example. Thus it would seem we are fully justified in rejecting the idea that the flora, alpine, forest, and arid, can have spread over all this country by natural means, under present conditions, and we are driven to inquire whether present conditions have always prevailed, or whether there might not at some period have been direct means of communication between the Indian and Chinese ranges.

Holding to our argument that the flora has probably travelled in a north-easterly direction from the Dihang bend, we find that a line drawn north-east from that bend passes across the Salween and Mekong rivers in the neighbourhood of their bends, which may be more abrupt than is shown on present maps, eventually reaching Kansu and the western end of the Tsin-ling Mountains. Major F. M. Bailey has discovered a peak just across the Dihang bend, which is on the main axis of the Himalaya; that is to say, the Dihang has cut through the main Himalayan axis, and it is not impossible that the Salween has done the same.*

Now both the Indus and the Dihang, as Sir Sidney Burrard points out, when crossing the main axis of the Himalaya, bend sharply. The Salween and the Mekong also change their direction, though more gradually, from east, or south-east, to south, so that they too may likewise

* I regret I have not had access to Prince Kropotkin's views on this region.

cross the axis of some great range. The direction of our supposed Sino-Himalayan range corresponds with the change of direction of these two rivers, and is parallel to the Ninchin-thang-la range of Tibet. It is to the south and east of the line that we find the Sino-Himalayan flora; to north and west the country passes rapidly into steppe and desert.

The inference then is that there was formerly some direct connecting range between the eastern end of the Himalaya and the western end of the Tsin-ling; and though there is lacking any direct evidence for the existence of this Sino-Himalayan range, what evidence there is points to this being the most profitable direction in which to seek it. Lastly, the Tsin-ling is the only east-and-west range extending across China which could carry Himalayan plants into the heart of China.

We come now to the question of distribution. It is not necessary at this stage of the inquiry to go into details, and I will confine myself to a broad review of the area.

First of all we have the general resemblance of the alpine flora from the eastern Himalaya to north-west China; no such resemblance is to be noted in the forest flora. Taking as a type some characteristic alpine genus such as *Primula*, we find that species increase as we go eastwards, the Himalayan groups of *Primula* attaining the greatest development in Yun-nan, as pointed out by Sir George Watt. This is equally true of other genera, such as *Rhododendron*, *Meconopsis* and *Pedicularis*. The same genera are well represented on the Tsin-ling, but the Himalayan relationship grows more distant as we go eastwards. On the Tsin-ling itself there are no Himalayan species.

Now turning to the mountain ranges of Yun-nan separating the Irrawaddy, Salween, Mekong and Yangtze rivers, we find that while their flora is very similar, it is richest in the south and west, that is, on the Salween–Irrawaddy divide, and each range possesses species not possessed by the others. North of lat. 28° the flora of the Mekong–Salween and Mekong–Yangtze divides is almost identical, but south of that there are striking differences. For example, *Primula Franchetii*, *Meconopsis Delavayi*, *Cassiope palebrata* and *Gaultheria sp.* found on the Mekong–Salween divide are absent from the Mekong–Yangtze divide. *Larix sp.* and *Meconopsis integrifolia* found on the Mekong–Yangtze divide are absent at least from the southern part of the Mekong–Salween divide, south of lat. 28°, and absent altogether from the Salween–Irrawaddy divide.

The Tsin-ling relationship of this flora is illustrated by the occurrence of species of the following *Primula* sections in both areas: *Mollis*, *Denticulata*, *Petiolaris*, *Candelabra*, *Omphalogramma*, *Soldanelloides* and *Malvacea*, though all of them, with the exception of the last named, have Himalayan representatives as well. As in the case of the Himalayan *Primulas*, these sections are all represented by more species in Yun-nan than they are on the Tsin-ling.

In the south the flora of these ranges is richer than in the north, as might be expected. Following them northwards, we find them presently turning north-west and diverging widely from each other, forest rapidly giving way to steppe and steppe to desert.

Taking the area between the eastern Himalaya and the Tsin-ling as a whole, we can recognize several distinct floral areas. For instance there is the Irrawaddy basin, whose flora is Indo-Malayan in the valleys, related to that of Assam, Arracan and Tenasserim; the alpine or Sino-Himalayan area; the south-eastern Tibetan area, with its arid flora, traversed by great mountain ranges carrying the Sino-Himalayan flora far to the south; and the Chinese area of central Szechwan and Yun-nan. The flora of the Irrawaddy basin from lat. 25° northwards is characterized by remarkable variety of *Impatiens*, *Rubus*, *Ficus*, *Begonia*, *Gesneriaceae* (*Aeschynanthus*, *Chirita*), *Acanthaceae* (*Thunbergia*, *Strobilanthes*), *Zingiberaceae* (*Hedychium*), *Aroideae* (*Arisaema*, *Amorphophallus*), together with species of *Pandanus*, *Musa*, *Pterospermum*, many palms (*Caryota*), bamboos, *Leguminosae* and *Dipterocarpaceae*. Even here, however, three peculiarly Chinese species occur, namely, *Wistaria chinensis*, *Rhododendron indicum* and *Rawolfia chinensis*, besides a number of plants known only from the eastern Himalaya, namely, *Hydrangea robusta*, var. *Griffithii*, *Æschynanthus maculata*, *Thunbergia lutea*, *Calanthe brevicornu*, *Polygonatum nervulosum*, *Arisaema concinnum* ('Records of the Botanical Survey of India,' vol. I, No. ii.).

The alpine area seems to be divisible into three sub-areas: (i.) the Eastern Himalayan, with no Tsin-ling species; (ii.) the Burma–Yun-nan, both Himalayan and Tsin-ling species; (iii.) the Tsin-ling, with no Himalayan species. The Burma–Yun-nan area, which includes also western Szechwan, is probably the richest of all. The Salween–Irrawaddy divide, even as far south as 26° lat., where the highest peaks rise little above 13,000 feet, is extraordinarily rich. Species of *Primula*, *Buddleia*, *Rhododendron*, *Viburnum*, *Rubus*, *Thalictrum*, *Codonopsis*, *Lonicera*, *Begonia*, *Impatiens*, *Magnolia*, *Clematis*, *Arisaema*, *Quercus*, *Cremanthodium*, *Polygonum*, abound; there are many *Zingiberaceae*, *Hamamelidaceae*, *Liliaceae*, *Orchidaceae*, *Aroideae*, *Lardizabalaceae*, *Araliaceae*, *Coniferae*; on the highest ranges are found *Meconopsis sp.*, *Cassiope myosuroides*, *Ypsilandra yunnanensis*.

It will be sufficient to observe here that the Tsin-ling flora includes many species of *Primula*, *Meconopsis*, *Rhododendron*, *Gentiana*, *Saxifraga*, which fully establish its relationship to the Yun-nan, and through that to the Himalaya flora. Of seventeen sections of Primula found in north-western China, eight have representatives in both the Himalaya and Burma–Yun-nan areas; one (§ *Malvacea*) has representatives in Yun-nan but not in the Himalaya; one (§ *Farinosa*) has representatives in the Himalaya, but not in Yun-nan; while the remaining seven sections are peculiar to this region.

The arid gorges of south-eastern Tibet along the Yangtze, Mekong, Salween, and Wi-ch'u support a special flora of their own about which little is known, at least as regards its relationships. It includes species of *Arisaema*, *Selaginella*, *Didissandra*, *Clematis*, *Berberis*, *Pertya*, *Stemona*, *Spiraea*, *Sophora viciifolia*, *Cheilanthes farinosa*, *Asphodelus;* but appears to vary in different valleys. Here again it is almost impossible that there should be transfer of species from valley to valley over the dividing ranges, except perhaps in the case of the Cryptogams.

To explain the presence of a flora showing Himalayan and north China affinities as far south as lat. 26° in Burma and 25° in Yun-nan, and the close relationship of the Himalayan and Tsin-ling flora, though these ranges are now separated by deep impassable river gorges; to explain also the similarity between the floras of the Salween–Irrawaddy, Mekong–Salween and Mekong–Yangtze divides, and their not less striking differences—these ranges being now separated from each other by deep river gorges—I have supposed an original connecting range between the Himalaya and the Tsin-ling, subsequently breached with the formation of a series of parallel north-and-south trending ranges which have cut right through this main axis, separating its broken ends. Further, that plants from both ends of the broken ranges were driven south through the breach down the new parallel divides by advancing ice during the glacial epoch.

The final result of such a sequence of changes might be somewhat as follows: To begin with, we have a single range, or rather series of close parallel ranges, stretching from Sikkim to China; it will carry an alpine flora, which will vary in different parts. After it has been breached, this alpine flora will be divided into three, a flora at each end of the broken range, and one in the middle, this latter being driven south by advancing ice. For the future these three areas are isolated from one another; but though their floras must differ, yet owing to their origin and the conditions under which they live, they will always bear the impress of a common relationship.*

The three areas may be represented diagrammatically as follows:

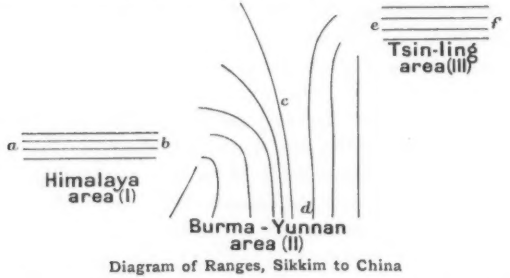


Diagram of Ranges, Sikkim to China

* I have given reasons, based on an analysis of *Primula* sections, for this division into three alpine plant areas (see *Transactions and Proceedings of the Botanical Society of Edinburgh*, vol. 27, Part I.).

It is clear that over an area so great and so complex as that with which we are dealing, the flora must differ in different parts of the same range—we know, in fact, that it does so. We may therefore note the following points: (*a*) The most westerly range of area (ii.) should show closer affinity with the Himalayan flora, the most easterly closer affinity with the Tsin-ling flora. (*b*) On any single range in area (ii.) the affinity of the flora with areas (i.) and (iii.) will be closer in the north, near the breach and in the line of the original connection, than it is in the south, where the floras have had time to become more mixed. Therefore also the floras of the parallel divides in area (ii.) should be more similar in the north, at *c*, than they are in the south, at *d*. (*e*) We should find a closer relationship in the flora occupying the internal lines, *b*, *c*, *e*, than we do in that occupying the external lines *a*, *d*, *f*. (*d*) If it was ice which drove the mixed flora through the breach, we ought to find some central China plants, with American affinities, as well as Tsin-ling plants, in area (ii.). The forests of these three regions would naturally not show the same affinities as the alpine flora, since they are subjected to more varying conditions. A mixture of Indo-Malayan forms will be found in many of the forests, especially in the more western valleys, while Chinese forms will be found especially in the east, from the Yangtze to the T'ung-ho.

We are now in a position to consider what line of investigation to take up, what to seek and where to seek it. The problem may be attacked in two ways: directly by geographical exploration, indirectly by botanical exploration. We might indeed look for some remnant of our Sino-Himalayan range in the direction indicated—that is, north-east of the Dihang bend. This implies an accurate survey of the country between the Dihang, where that river crosses the main Himalayan axis, and the Kansu–Szechwan frontier where the Tsin-ling emerges as a coherent range from the knotted mass of mountains fringing the Tibetan plateau; since it is only from large-scale maps that the lines of great peaks, indicating the probable main ranges, can be followed.

Such remnants, if they have survived the obliterating changes which must have overtaken this region, are more likely to be found at the Himalayan end of the breach than further north-east; and since many years must elapse before the whole of this area can be properly surveyed, it is there that I propose to seek them.

We may now consider the indirect method, botanical exploration the main line of investigation. Briefly, we require to seek whether the results already stated as likely to follow, if the sequence of changes suggested really took place, have in fact followed.

Taking these in order, we must first define the limits of our three areas, and compare their floras as fully as possible—a task to be undertaken in the herbarium. Next we must compare the flora of the western irruption ranges, say that of the Salween–Irrawaddy and Irrawaddy–Zayul divides,

with that of the Himalaya; and as we know nothing of the flora of the second, and very little of the first, there is scope for plenty of botanical exploration on these ranges. Similarly, we must compare the flora of the easternmost ranges, say those lying north and east of Batang and round Tatsienlu, with that of the Tsin-ling. Of the former area next to nothing is known botanically.

Taking now the best-known ranges of the Burma–Yun-nan area, say the Mekong–Yangtze and Mekong–Salween divides (though the latter is untouched in the south for a hundred miles), we must compare their floras in the north and in the south, say lat. 30° for the north and lat. 26° for the south. According to our theory, there should be a closer relationship brought out in the north than there is in the south. We know nothing about the flora of these divides north of lat. 29°, and practically nothing about them in the neighbourhood of 26°. Collections made on the Mekong–Salween divide in the neighbourhood of Menkong (lat. 28° 30′) would be invaluable; we know something about the flora of the Mekong–Yangtze divide in this latitude, from collections made at A-tun-tzu.

A corollary to the above is, that the flora on the northern part of the Mekong–Yangtze or Mekong–Salween divide will differ from the flora on the southern part—probably more than it does over the same length of Himalayan range. This difference might be less marked on the Salween–Irrawaddy divide than on the others, for reasons which will be stated presently.

Again, we can test our third deduction, namely, that the floras of the internal area *b*, *c*, *e* will show nearer relationship than those of the external areas *a*, *d*, *f*. Here indeed is scope for an immense amount of botanical exploration, for while the flora of Sikkim may be taken to represent *a*, that of the A-tun-tzu region as *c*, that of the Hpimaw and T'eng-yueh regions as *d*, and that of the Shensi-Kansu border as *f*, nothing whatever is known of *b* (the extreme eastern limit of the Himalaya), and practically nothing of *e*, where the Tsin-ling stretches far into Tibet. Moreover, area *c* is very imperfectly known, since it includes the almost unknown Salween–Irrawaddy divide and the quite unknown Irrawaddy–Zayul divide.

Finally, experience shows that the parallel divides in area (ii.) grow richer in species as we travel westwards, the Salween–Irrawaddy divide being apparently the richest of all—as it is the least known. We may well ask ourselves what happens on the great ranges which thrust down their snowy peaks between the Irrawaddy and Zayul rivers and between the Zayul and Dihang rivers. Is their flora even richer than that of the Salween–Irrawaddy divide, as appears not improbable? Has it still closer Himalayan affinities—is it, in fact, a direct link between the Eastern Himalayan flora of area (i.) and the Burma–Yun-nan flora of area (ii.)? Have any Chinese forms from area (iii.) and central China reached as far west as this? All these questions require answering.

It is clear that all we can do at present is to select certain spots and

make collections of plants from them for later comparison. And since many of the plants with which we are concerned are showy, and can be raised from seed in England, it is always an advantage to collect seed as well as herbarium material, and grow the plants themselves in England.

The ranges which specially call for exploration, then, are the Salween–Irrawaddy divide in the north, the Irrawaddy–Zayul and Zayul–Dihang divides, neither of which have been touched; the extreme eastern end of the Himalaya, the mountains north of Batang, and the Tsin-ling west of Tao-chow in Kansu. Much botanical exploration has been carried out in this region during the last twenty years by the French Catholic priests, by Mr. E. H. Wilson, Mr. G. Forrest, Mr. Purdom, and Mr. R. Farrer; but much more remains to be done, and the more one explores the country the more one finds to explore.

In a general way also we require to know where the alpine flora of the area (ii.) ceases and passes into the barren ranges of Tibet; where is the northern boundary of the Indo-Malayan flora which spreads up the valleys of the Brahmaputra tributary rivers, the Irrawaddy tributary rivers, and the Salween; how far east Indo-Malayan plants are found, and how far west Chinese plants.

When we come to area (ii.), where most of the exploration indicated has to be carried out, we find yet further matter for investigation. On the parallel ranges in the neighbourhood of A-tun-tzu there are indications of a very considerable retreat of the glaciers, which however seem to have retreated much further on the Mekong–Yangtze divide than they have on the Mekong–Salween divide; and it would appear that precipitation has been screened off the easternmost ranges one by one, by the gradual and consecutive uplift of ranges in the west.

How far, if at all, the ice has retreated on the Salween–Irrawaddy divide is matter for investigation. At present this range seems to divide the Indo-Malayan flora in the west from the Chinese flora in the east. The extensive retreat of the glaciers all over western China may date from the glacial epoch; it was during the advance of the ice at that time that the Atlantic American flora was driven far south into China, spreading, no doubt, from the Arctic circle, where it flourished in Tertiary times, down the Atlantic coast of America, on the one hand, and south-west into China, *viâ* the Aleutian Islands, on the other. For the reason that conditions seem more stable on the Salween–Irrawaddy divide than on either the Mekong–Salween or Mekong–Yangtze divides, it may be that the flora is more uniform along this range than along any other. But the desiccation of the Yun-nan ranges by the uplift of newer and higher ranges in the west, which capture the bulk of the rain coming over from Burma and Assam in the south-west, has certainly disturbed the alpine flora on the ranges in area (ii.).

Here I must end, with the task barely outlined. It is a pretty problem to be solved on this ground where Himalayan, Malayan and Chinese floras meet. Let us see what light the next assaults on it will throw.

ECONOMIC NOTES ON EASTERN TIBET

Oliver Coales, H.B.M. Consular Service

Map following p. 264.

THE following notes are supplementary to an account of a journey in Eastern Tibet that appeared in the April number of the *Journal*, and accompany the map which is now published.

In 1917 the Chinese had control of a district of approximately 80,000 square miles in area (exclusive of Koko Nor). From a calculation I made then, on the basis of the number of families in the districts into which the Chinese had divided the country, I estimated the population to be about 450,000 persons, an average of less than six to the square mile. Probably more than one-tenth belonged to the celibate lama priesthood. Chinese settlers and half-castes living as Chinese were not more than 25,000 and lived almost entirely at Tachienlu, in the districts near that town and at Batang. There were also about 7000 Chinese soldiers in garrison. During 1918 the Dalai Lama recaptured Ruvoch'e, Ch'amdo and Draya west of the Yangtze.

The three principal frontier marts on the Chinese or eastern side of Tibet are Tangkar (Donkyr) in Kansu to the west of Sining, Tachienlu and Atuntzu in the north-west of Yunnan. The first, Tangkar, is outside the subject of these notes, but a few words may be of interest. This busy little town has been vividly described by Abbé Huc in his 'Travels in Tartary.' The road from Tangkar to Tibet joins the north road from Tachienlu at Jyekundo. Towards the east one road leads to Lanchow, the capital of Kansu, and another branches off east of Sining and goes through Liangchow across Mongolia to Kweihwacheng, where merchandise is transported to Tientsin. Through Tangkar passes the greater part of the trade between Tibet and North China. The staple commodity is wool, of which some 2,700,000 lbs. are exported annually to Tientsin. In this trade Tangkar completely overshadows Tachienlu, a fact which is partly accounted for by the cheapness of camel transport across Mongolia. As a matter of history it may be mentioned that up to the establishment of the Manchu dynasty in China and the conquest of Tibet, intercourse between the two countries was mainly carried on by this and other roads through Koko Nor and not through Tachienlu. Other exports through Tangkar besides wool are lambskins and salt, and the principal import is barley, a necessity owing to Koko Nor being a pastoral country.

Atuntzu, a small town in the extreme north-west of Yunnan and due south of Batang, is important because it lies on a road leading from the principal towns of Yunnan to Batang and to the districts south-west of Ch'amdo. Its trade is comparatively small, because Yunnan supplies neither tea nor silk and the Tibetan country beyond it is not a pastoral region. The chief export is musk.

Tachienlu owes its importance to the tea and silk which are produced in Szechwan for the Tibetan market. The means of access from the east and west are far less favourable than those of Tangkar. The latter is approached by good mule roads from Kansu, and on the west, though the road to Tibet passes through a very elevated country, there are no passes of great difficulty. On the other hand, the road from Chengtu to Tachienlu crosses a rugged mountainous country involving two steep passes of over 9000 feet altitude, a descent to the Tung River and a climb of 5000 feet to Tachienlu. The road has been improved by the Chinese, much of it being paved with stone slabs, and the ascents of the passes are flights of steps just passable by pack-animals. The Tung River is spanned at Lutingchiao by an iron suspension bridge constructed in the eighteenth century. I mentioned above that Chinese intercourse with Tibet prior to the Manchu dynasty generally passed through Koko Nor. In the earlier histories the route from Szechwan to Tibet always spoken of is a road leading westward from Sungpan, and Tachienlu is not mentioned till the seventeenth century. Locally one hears that the tea carriers formerly used a road along the Tung River westwards to its great bend at Tzutati, and thence into the Tibetan country west of the Cheto pass, finally joining the north road near Dau. The traces of their ironshod poles in the stones are still visible. It may be added that in former days the capital of the King of Chala was not Tachienlu, but a place further to the south-west.

The principal imports into Tibet from China are tea, silks, tobacco, cottons, foreign and native sundries, and rice. The latter is imported for the consumption of the local Chinese and army. Had the Szechwanese, like their countrymen of Kansu, been wheat instead of rice eaters, their attempts at colonization might have been more successful than they have actually proved. The sundries and cotton goods are also generally required by the Chinese, the Tibetans, in place of the latter, preferring woollens, locally woven or from Lhasa, or, if wealthy, silk. Tobacco is a luxury which every Tibetan now requires

Tea and silk are the bulk of the import trade. As far as the production and transport of tea to Tachienlu are concerned, the tea trade has been exhaustively described by Sir A. Hosie in his 'Journey to the Eastern Frontier of Tibet, 1905,' and by other travellers. The trade has suffered greatly from the continued hostilities between China and Tibet, and imports have fallen off in recent years. To the Tibetans however tea is a necessity of life, and they have put no artificial restrictions on its importation. Judging by inquiries made at Tachienlu, Chinese tea holds its own in spite of political difficulties and is not being ousted by Indian products. The competition of India tea is not alleged as a reason for the decreased use of China tea, and probably the Tibetan trade is too small to make it worth the while of Indian planters to specialize in it.

Silk goods imported through Tachienlu are silk piece-goods, katas or ceremonial scarves, coloured scarves, and cords. They are made in

Chengtu specially for the Tibetan market. In China the favourite colour in dress is blue, but the Tibetan prefers maroon, dark red, or yellow, and these colours predominate in the silks which are imported. In figured cloths all the Chinese designs are popular, but the weavers also manufacture many Tibetan styles, bearing figures of Buddhas, pagodas, or religious emblems. The best qualities, amongst them brocades in gold thread, are fine examples of the weaver's art. The value imported in 1915 was about £20,000, and that of tea £170,000.

Tibet exports to China musk, gold, wool, skins, and medicines. Musk is the produce of a small deer which is found all over Tibet. It is easily adulterated, and experts are required to purchase it. About half a dozen firms specialize in the trade, which amounted in 1915 to £160,000. It is of sufficient importance in the European scent industry to cause two French firms to maintain themselves at Tachienlu and Atuntzu solely for this commodity. Gold is next in importance to musk. Though much is mined in the country, a large quantity is brought from India through Lhasa to pay for tea and silk. As regards wool, the scarcity caused by the Great War and the higher prices prevailing tempted merchants in recent years to bring down much larger quantities than ever before, but the boom is not likely to continue if prices fall. In former years the wool trade of Tachienlu was a mere fraction of that of Tangkar. The medicines exported are mainly rhubarb and other vegetable drugs for the Chinese market. The most interesting is the curious Chungtsao or insect grass, a dried caterpillar about 2 inches long, which has been killed by a fungus of about the same length growing out of one of its segments. It is supposed to be an excellent restorative to weak constitutions.

At Tachienlu imports and exports change hands from Chinese to Tibetans and *vice versâ*. Till recently the handling of trade in Tibet was done by Tibetans, and though the Chinese are more and more engrossing trade in the occupied districts, that with independent Tibet is still done by Tibetans. In general it is monopolized by merchants of the eastern province, Kham, either private people trading on their own account or on behalf of monasteries, or monasteries themselves. The wealthiest merchants belong to the Horpa States.

The ordinary course of trade is this. A merchant, say at Lhasa, wishing to purchase tea and silk, assembles a caravan of ponies and mules and lades them with Tibetan goods, such as woollen cloth, rugs, incense, foreign sundries from India, and gold and silver in bullion or coin. He proceeds to Tachienlu by the north road through Jyekundo and Kandze, selling his stock as he goes along, so that little reaches Tachienlu. Here he puts up at one of the Tsang or Kwochwang. These are the houses of the local Tibetan gentry, who undertake to entertain the merchants on condition of being their go-betweens and interpreters in dealing with the Chinese. There are commonly said to be forty-nine of these Kwochwang, but there are really only about half that number.

When business is to be arranged, the Kwochwang owner takes the merchant round to the Chinese merchants he wishes to see. In the old days the tea business was a close monopoly of a few Chinese, and the Tibetan, who usually traded with an old-established connection, was practically obliged to take what the seller offered at the latter's price. Circumstances have changed with the decrease of trade and the opening of many new Chinese firms, so that the touting is now on the Chinese side.

The Tibetan now begins to arrange his contracts. The general custom is for the buyer to pay one-half of the price on the spot in cash and to give a promissory note for the remainder. He engages to remit this balance when he next comes to Tachienlu. In the meanwhile he has been paying off old debts and purchasing sundries and silks. Cash in full is generally paid for these. The arrangement of the tea contracts is a long business which may keep the merchant some months in Tachienlu. During this time he is able if he wishes to have silk piece-goods made to his order at Chengtu.

Everything having been settled and his purchases made, the merchant collects the caravan, which has been let out to graze in the mountains, lades it with his silks and sundries, and sets out for the return journey. The tea will not have arrived before he leaves, and he will have to arrange with the Kwochwang landlord for its packing and transport after he has departed.

The tea is brought in day by day from China, and as it comes is repacked and stored till sufficient is collected for a caravan. As delivered in Tachienlu the tea is in packages $3\frac{1}{2}$ feet long, 8 inches wide, and 4 thick, wrapped in bamboo matting. To reform for animal transport three packages are cut in half, the halves placed side by side and wrapped in raw hides, which are tightly stretched and sewn while fresh and damp. A stiff, unbreakable bale, 22 inches square by 8 thick, is thus made. It weighs about 66 lbs., and two or 133 lbs. form one animal's load. Generally all kinds of merchandise for Tibet, whether in boxes or not, are packed in a similar fashion in raw hides.

By the time the tea is ready a caravan of yaks has been hired from one of the firms who specialize in this business, and the tea is loaded on the animals and despatched. Such caravans do not make the whole journey to Lhasa, but are changed every half a dozen stages or so. They are almost always of yaks, and their slow rate of travel and the delays in changing over make the journey to Lhasa a very long one. Mules and ponies are hardly ever used for this purpose, being preferred for more valuable merchandise, such as silk and sundries. The merchant will have arrived in Lhasa long before his tea, and it may be a couple of years from the time he first set out to Tachienlu till the last consignment arrives. As regards the payment of the balance, he will settle this on his next visit to Tachienlu, and Chinese say that defalcation is a very rare occurrence.

In respect of its mineral wealth Tibet is probably the least known

country of the habited world. No scientific geological expedition has ever touched more than the fringe, and over the greater part the geological features are sketched on mere conjecture. Richthofen's Geological Atlas of China gives some general features in South-Eastern Tibet, but only a small portion of his data is taken from direct observation.

The wide distribution of alluvial gold deposits may indicate great wealth of this metal. Gold is found in every part of the country east of the Yangtze River, but not, as far as I have heard, between the Yangtze and the Mekong. The Tibetans have a superstitious objection to removing precious metals from the earth, believing that they contribute to its fertility. The Chinese however are less scrupulous, and their activities have often led to conflicts with the natives, more especially when the gold-bearing sands lie beneath the Tibetan fields. The yield of gold is generally poor, and a Chinese would consider himself unusually fortunate if he made £150 to £200 a year. The usual method of cradle washing is employed, the concentrates being finished off with quicksilver. The discovery of a new field leads to the usual gold rush, but after a year or two the cream of the mine is skimmed off and a few stragglers remain to clear up the leavings. None of the mines I have heard of have lasted for any length of time. At the present time the most flourishing is at a place 50 miles north-east of Dau, where several thousand Chinese are engaged. It appears to be in a rich mineral district, as other ores are to be found, including native silver.

Silver is found at the place just mentioned and also near Tachienlu. In this latter mine, where gold has also been found in alluvial gravel in a fissure of the limestone, some veins of silver-bearing galena are exposed. A Chinese company worked the mine for silver for a short time, but stopped after losing money in the enterprise.

Copper has been mined for a long time at Kungkaling, to the south of Litang and west of the river Yalung. It is from these mines that the coppersmiths of Dege obtain their metal. Copper ore has also been found in Dege at Wara Gompa on the river north of T'ungpu. A mine was opened in 1910 or thereabouts, but has since been closed.

Tin is apparently not found in Eastern Tibet, for no mention of it is ever made. The white alloy of tin used in Dege in metalwork is imported from China.

Iron ore mines may exist in South-east Tibet, but none has come to my knowledge. It is probable, however, that the swordsmiths of Dege obtain their iron locally. Most of the iron utensils used by the Tibetans come from Szechwan. At Ch'amdo they are said to come from Shobando, in Tibet west of the Salween.

There is no evidence of extensive coalfields, the only mine I have heard of being a small working on the Ba River 30 miles north of Batang, which is now closed. There are however some mines east of the Tung River near Lutingch'iao.

One useful mineral recently discovered which should be available for the foreign market is white mica, which has been found on the upper course of the Tung River 100 miles from Tachienlu near Romidrango. An enterprising Chinese was able to contract with a Hankow firm for the supply of mica sheets on marketable terms, but the war had put a stop to the works when I left Tachienlu in 1918.

The principal obstacles to modern mining enterprise in this country, apart from Chinese official obstruction, would be lack of labour and difficulty of transport. The former could no doubt be overcome by importing Chinese labour from Szechwan, but it would be quite impossible to feed them on local resources. All food would have to be brought from Szechwan. Machinery of moderate size might be brought by water as far as Chiating in Szechwan on the Yangtze, but beyond that it would have to be brought overland. The difficulties of the road to Tachienlu, which have been pointed out above, make this impossible. It is quite unlikely that any railway will be built even to Tachienlu—there is none yet in Szechwan itself—for the volume of traffic would never justify the enormous expenditure. Therefore any mining company that proposed to undertake large operations would have to build its own railway for purely mining purposes, such as the internal railways of Western Australia.

The map which is published at the end of this number of the *Journal* gives a detailed reduction of a route traverse I made with prismatic compass and sextant in 1916. The journey was described in the April number of the *Journal*. The original sheets, which are fourteen in number, are plotted on a scale of 2 miles to the inch, and record every town, village, and solitary house, and every monastery passed on the road. The average number of compass sights taken was at least two to the mile, often as much as three. The road from Gönchen to Ch'amdo had been travelled by Europeans before but not mapped; that from Ch'amdo to Batang is almost entirely new, while that from Batang to Gönchen had also never been mapped in detail. In the original sheets the shape of the country has been indicated by form lines as accurately as possible in a hurried compass traverse.

LIGHT RAILWAYS IN NEW COUNTRIES

Major W. Waters Van Ness, R.E.

I HAVE been tempted into giving the results of my experience and expressing my views on light railways through reading Colonel Napier's very interesting and instructive paper published in the January issue of the *Geographical Journal* on "The Road from Baghdad to Baku." I note that both Colonel Napier and Sir Valentine Chirol advocate motor transport in preference to railways for solving transport difficulties in Persia.

Light railways of 30 cm. (2 feet) gauge have many points in their favour for such a country as is described by Colonel Napier; they can be constructed with greater rapidity and more economically than standard gauge lines, and in most cases are much cheaper to operate than motor lorries. It has been proved by experience that petrol or steam driven lorries can only compete with light railways as collectors and distributors where the source or destination of goods is too uncertain, or the tonnage too small, to justify the construction of a light railway line, or in a thickly populated country where the cost of a right-of-way for a light railway would prove prohibitive, and where motor roads are already in existence, maintained at government expense.

On the western front of the British Army in France, where many thousands of tons were transported by both means, and where, owing to the previous existence of a network of motor roads, the conditions were more favourable for motor traffic than at present in such countries as Persia, it was proved that motor transport on the whole could not compete with light railways either in cost per ton hauled, or in reliability. All the data I have been enabled to collect, together with my own personal experience in civil life, and in the operation of military light railways in France, point conclusively to the fact that a light railway can be constructed cheaper and quicker than a road to carry motor traffic, and costs much less to maintain.

It has been proved in actual work over long periods, both on the western front and elsewhere, that on the whole light railways using petrol tractors or steam locomotives can handle traffic at considerably less cost than is possible by any class of motor lorry in any country where the cost of a right-of-way would not be excessive. The difference in favour of light railways should be very pronounced on lines over 50 kilometres long carrying 800 tons or more per day in either direction over each 50 kilometres, or on a group of short lines in the same district which could be administered by the same management.

On light railways carrying large and regular traffic it has been found that light steam locomotives are the most economical and efficient. They can be fitted to burn either wood, coal, or petroleum according to the country in which they are operating.

I quite agree that in Persia standard gauge railways (with the possible exception of a main trunk line traversing the country) would prove unprofitable at present, owing chiefly to the large capital outlay necessary for construction and equipment; and to pay they would require a considerably larger tonnage than is likely to be available in Persia at present. But a light railway line can be constructed much cheaper and quicker than the standard gauge. Its narrow gauge can negotiate curves as sharp as 30-metre radius and gradients up to 3 per cent., and the road bed of one-half the width will allow greater flexibility of route for traversing a hilly country.

I am not familiar with Persia; but in the hinterland of Asia Minor I was greatly impressed with opportunities for the profitable employment of light railways. There are many routes to choose from along which a light railway should secure a remunerative traffic from the start, especially those traversing large valleys which are fertile and productive, bordered by mountains abundant in emery, manganese, chrome iron, antimony, copper, and silver-lead ores. Along these most promising routes for light railways there are now only trails or very rough roads; the present produce, chiefly emery, dried fruit, hemp, grain, liquorice, wool, and hides, is carried by camels and an occasional buffalo-cart.

In some places the mountain slopes are covered with good timber, including pine and walnut, which owing to lack of transport had up to just before the war remained unexploited.

At the base of the mountains, especially in the valley of the Gediz river north-east of Sahhli, are mineral springs both hot and cold, many still with marble baths constructed by the Greeks. In one place about 8 miles south-east of the village of Simav and 35 miles north-west of Ushak I found a group of boiling geysers of highly sulphurous water, picturesquely situated in a pretty valley, where a large number of women were taking the baths, and I was informed that many came great distances each year for this purpose. Thus in addition to ordinary freight traffic some passenger traffic can be anticipated, especially in the summer season.

The following are amongst the most promising of the light railway routes of which I have made a reconnaissance, all of which should yield a remunerative traffic from the start.

1. From Odemish to Baliamboli, 20 km. Traffic: Antimony ore, agricultural produce, and walnut.

2. Aidin to China, 50 km.; possible extension to Mughla, 50 km., and Marmarice, 50 km. Traffic: Emery and copper ore, agricultural produce, liquorice root, wool, hides, merchandise, and passengers.

3. Sahhli to Borli, 50 km. Traffic: Agricultural produce, liquorice root, merchandise, tan bark, minerals, and passengers.

4. Balikesri to Simav, 150 km.; possible extension to Ushak, 80 km., and Chivril, 70 km. Traffic: Agricultural produce, wool, hides, merchandise, minerals, timber, and passengers.

PROBLEMS OF EASTERN EUROPE

The New Eastern Europe.— Ralph Butler. London: Longmans, Green & Co. 1919. 10*s.* 6*d. net.*

ALMOST all the books dealing with the geography of man and relating to the pre-war empires of Germany, Austria-Hungary and Russia will now have to be re-written, not merely on account of the political bias that they manifested, but also because so many important facts were purposely

overlooked. This is essentially true of books dealing with that region of Eastern Europe which, until recently, formed part of the Russian Empire, where the Imperial censorship was the most drastic. If any books have thrown light on such subjects as the Baltic provinces, Lithuania, Ukraine, or even Finland and Poland, it has usually been not the scholarly works, which of all have been the most influenced by political "points of view," but books of travel written by unprejudiced observers. Mr. Butler's book on the 'New Eastern Europe' stands nearer to the second type of literature than to the first. It reads like a well-written correspondence to a daily paper rather than a series of articles collected from the monthly reviews in which they have appeared. They were apparently written in the second part of the war, when the demand for facts was most acute in the English press, and they give one chapter to each of the western border countries of the Russian Empire, and three chapters to Poland.

The chapter on Finland reads almost the best owing to the impartiality of the observer and to the ingenious way of generalizing by which he has made clear to the British public facts which taken separately would be unintelligible. But he makes the mistake common to all writers on that country; that is, he uses the linguistic term "Finn" when dealing with the Finns of Finland. Possibly the term "Finlander" has an uncouth sound to the British ear, but then some other term may be invented to distinguish the people using the Finnish language and inhabiting Finland from the Finnish-speaking people who inhabit Great Russia and Western Siberia, and who are not conscious of any kinship with Finland. Knowing that the Finns were the aborigines of what is now called the most real Russia, and that, though they were to a great extent swamped by their Slavonic invaders, they still preserve in many places their separate language and culture, it is impossible to adhere to Mr. Butler's remark that "Russia will be the healthier for the excision of this non-Slavonic element" (p. 20). No national movements can undo the blending of Finnish and Great Russian blood, for which the heart of Great Russia, the upper Volga, is the centre; but one has to agree with Mr. Butler's principle that Russia will be healthier if she has no more Finlanders, whether of Finnish or Swedish tongue, within her borders. In his account of the historical development of Finnish independence, the author refrains from predicting the future of the country, unless we take as such his remark that Finland ". . . has no mission to the world; the only mission of which she is conscious is to herself" (p. 20). Seeing that all the troubles arising from the present boundary-making in Europe are based on the abnormal development of various peoples' mission to the world, it is just as well that there are people who, it is hoped, will not quarrel with their neighbours on account of their consciousness of a "higher call."

The chapter on the New Balticum is better in its historical part than in the representation of the actual problem of to-day, and it calls for some further amplification, as, for instance, is found in the article on the Eastern Baltic by a Harvard University Professor in the *New Europe* of 7 August 1919. The historical analysis of the various peoples who lived along the Eastern Baltic before the Germans colonized it, and the Poles, and finally the Russians, conquered it, can only be of political use in so far as it helps to make clear what is the present predominant nationality which may be able to deal with the existing problem. Will the Balts, Letts, and Esths, and perhaps even the Lithuanians, be content to sink their nationality in some union under a generic name such as that of Jugo-Slav, invented for the Serbs, Croatians and Slovenes? The difficulty is that no prediction for the future can be based on

the past because, with the exception of the Lithuanians, none of them have a history as have the Serbs, Croatians and Slovenes.

Again, the chapter on the new Lithuania, just as that on the Ukranian (Ukrainian?) Movement, lacks the historical introduction necessary to enable even a well-educated Englishman to understand the problem of to-day. All that the author has to tell about the Lithuanians before the Russificatory period beginning in 1864 is that their language is the oldest in the European tongue. This truth is most interesting from an archæological point of view, but it has no more bearing on the existing problems than have the linguistic curiosities of Albanians and Basques. What does play a *rôle*, however, in the national consciousness of the Lithuanians is their history in the pagan period of the twelfth, thirteenth, and fourteenth centuries, when Lithuania formed an empire including White Russia, and a great part of what is to-day called the Ukraine. True, the language and institutions adopted in this empire were nearer to the White Russian and Ukrainian than to the Lithuanian, but the military power rested with the Lithuanian princes. The next important period in the history of Lithuania begins after her union with Poland in 1386, and finally in 1569, when she entered as an equal state while White Russia and part of the Ukraine were subjugated to Poland. In the second, or Christian period, of her history, as in the first, the language and institutions were foreign, namely Polish. The modern national movement in Lithuania does not cover the territory of her historical conquests, but is limited to the few provinces where the Lithuanian language is predominantly spoken, *i.e.* in the provinces of Kovno, the greater part of Suvalki, Grodno, and Vilno, and parts of East Prussia. The rising of the Lithuanian "intelligentsia" which gave an impulse to the national consciousness of the Lithuanian peasants, is even more recent than that of the "intelligentsia" of the Ukraine, and the difficulty of standardizing the language and of using it for more than colloquial purposes is also immense. But the homogeneity of the Lithuanian race and their historical past make of them a nation of a better defined individuality than either the Ukrainians or any of the Baltic peoples possess. This point Mr. Butler scarcely touches upon, devoting most of the chapter to the relations between the Lithuanians and the Russians and the Poles.

In his dealing with the Ukrainian movement, he quite rightly lays stress on the land question, which possibly promoted the recent agitation among the Ukrainian peasants just as the Austro-Russian rivalry and occasional interference on the part of the Poles promoted the agitation of the Ukrainian "intelligentsia." But how can the Ukrainian movement, whether that manifested by the peasants or by the "intelligentsia," be understood without referring back to the time of original Cossackdom and following its evolution from Ataman Sirko, the ideal organizer of the men's clubs, modelled on Western ideas, among the Slavo-Turkic people, till the re-organization of the Cossacks under Catherine the Great as a weapon of her autocratic rule? The history of the Cossack ought to be studied by every one who wishes to follow the Ukrainian question of the moment, even though it is now mainly an economic question, since no Mazeppa or Chmielnicki has arisen to unite in the Ukraine the nationalism of the peasant with that of the "intelligentsia."

The three chapters on Poland were of particular interest at the times when they appeared in 1917, 1918, and 1919; though so much has been written recently on the same subject of a very thorough character, that their chief value lies in giving the atmosphere surrounding the Polish question at these three particular dates. The chapter on Poland in 1917 is perhaps the most informa-

tive, while that of 1918 seems to be the weakest, both in spirit and in matter. It would have been of great advantage to the book if the last part of this chapter was altogether omitted where the author deplores that the Poles did not introduce compulsory military service, when it is now well known that the refusal of General Pilsudski to give a Polish army to the Germans, however sad in its immediate results for Poland, won in the long run her independence, and saved many unnecessary complications in Eastern Europe. Mr. Butler looked upon the Treaty of Brest-Litovsk more seriously than could have been expected from a careful observer of his standard, but even that which is probably the most disputable part of the book will prove valuable material for a future historian dealing with the time immediately preceding the Allies' victory. The chapter on Poland 1919 is the least important of all in the book, being merely a discussion of party and leaders' differences as they appeared outside the country, and overlooking the very striking events inside Poland which accompanied her re-birth. One feels that Mr. Butler's most valuable contributions are those written under the first impression, and that he loses his power of generalization when dealing with events at a distance of time and place.

In spite of all shortcomings, the majority of which are due to the fact that his work lacks the plan of a book, the 'New Eastern Europe' stands unique among many contributions that have appeared on the subject and which bear a more scholarly stamp, and one can only wish that Mr. Butler may not cease travelling and writing on what he sees, thus providing material to the advantage of geographer and historian. M. A. CZAPLICKA.

REVIEWS

EUROPE

Wanderings in Italy.— **Gabriel Faure.** London: Heinemann, 1909. *7s. 6d. net.*

Byways in Southern Tuscany.— **Katharine Hooker.** London: T. Fisher Unwin. 1919. *18s. net.*

M. FAURE'S book is the harvest of many happy autumn holidays in Italy, during which, we gather, he always managed to get a glimpse of at least one of the lakes, since to him they are dearer than anything else the country has to offer in the way of scenery. M. Faure is a man of letters, well versed in the literature of Italy and perfectly at home with the writings of the many Frenchmen who have travelled there before him. Italy is to him a beautiful land, though largely a land of memories, and above all the home of the great artists and architects, whose work inspires so many pages of his book. Of modern Italy and the modern Italians he has nothing to tell us. He was privileged to visit Aquileia and the portions of the old Venetian territory recovered before Caporetto, but even here he is concerned only with the museums and with memories of the past. Within these limits he has certainly given us a charming guide-book to the many parts of North Italy with which he is familiar. In Piedmont-Lombardy he keeps principally to the lake district; then he traverses the entire length of the Via Aemilia, from Piacenza to Rimini and visits Perugia and Assisi. But he has most to tell as of the Veneto, where he explores the canalized Brenta and visits Este and Arquà, Aquileia and Udine as well as Trent, Trieste and the Dolomites.

Miss Hooker's book, with its numerous photos and illustrations, is a description of the portion of Tuscany lying to the south of Siena. The region is not particularly well known, and she systematically explores the

numerous castles and strongly fortified villages with which the centrifugal spirit of the vigorous Italian middle ages has so thickly studded it, often in such detail that it is difficult to disentangle the endless battles and sieges of which they were the scene. History is Miss Hooker's chief interest, but she has something to tell us of the nature of the country ; nor does she forget altogether the Italians of to-day, the hotel-keepers and occasional peasants with whom she came in contact, though the motorist cannot hope to get into touch with them so successfully as the humble pedestrian ; and she has a distinct weakness for brigands. Along the sea coast lies the malaria-stricken Maremma. Like the Roman Campagna, it was a rich and flourishing region until the inroads of the barbarians began the ruin which was completed by the determination of Siena to break up the great feudal holdings at all costs. Rich it has always been, but it could be successfully developed only by farming on a large scale. Not till the last few years have scientific methods been applied to reclaim it. Drainage canals and the destruction of the mosquito are bringing a well-deserved reward to the large proprietors or syndicates undertaking the work, while they are restoring to the whole district the " buon' aria " which was hitherto only to be had on the higher ground. L. C. M.

ASIA

The Land of Promise.— Rev. H. G. Harding. London : Church Missionary Society. Pp. 116. *With a coloured frontispiece* (north-east end of Jerusalem and Nebi Samwil). 1919. 2*s.* 5*d.*

This little book is intended to provide knowledge which is essential to those who would form a right judgment of the country and its people and of "the forces which have been and will be at work when determining its development in the future." It presents a very fair picture of the life of the Fellahin, the Bedouin and the Jew, a sketch of the various religions, and an outline of the results and prospects of missionary work in the land. The author, as one to whom the rights of indigenous peoples of the land are of paramount consideration in any future settlement of Palestine, views the aims of "political Zionism" with considerable misgiving. He writes, however, with sympathy of Jewish colonies which he says are "redeeming the land, developing its resources, improving methods of cultivation." There is much in this book which will be new to those who have not lived in Palestine, and which it is desirable at the present time should be widely known.

E. W. G. M.

AFRICA

A Comparative Study of the Bantu and Semi-Bantu Languages.— Sir Harry H. Johnston, G.C.M.G., K.C.B., D.Sc. (Cambs.). Oxford : Clarendon Press. 1919. 4to. Pp. 812.

The first volume of this monumental work, which has recently been published, gives some idea of the enormous amount of work devoted to the subject by its author. It has been a labour of love, and is the result of many years' study of these African languages by one who is probably a greater authority on them than any other man, living or dead.

The production of the first volume does not only represent a vast amount of labour and research ; it has entailed heavy financial expenditure by its author. Meanwhile the second volume is delayed owing to the expenses attaching to its publication. This is a standard work, and will be a book of reference for all time. It would seem lamentable that its completion should be long delayed, and I can hardly think it likely that the necessary funds will not be soon provided—either by Government or through private channels.

At this time—when our Imperial possessions in Africa are so great, when development is proceeding so rapidly, and when a comprehensive knowledge of African languages is so essential for our Government officials, traders, missionaries, and others interested in this great tropical continent—a book such as this is a national asset. It is not in the class of literature which can be expected to bring in any money profit to its author, and it is a rare thing to find any one bold enough to undertake such a work. When found, he should be supported.

The first volume consists for the most part of vocabularies which have been laboriously compiled, partly by Sir Harry Johnston during almost the whole of his life, partly by the collaboration of numerous friends who have assisted him to collect them. The first two chapters, however, are devoted to, (1) a history of research, from the earliest days of which records are available, into the Bantu languages; (2) a consideration of the distribution and characteristics of the Bantu languages. Both of these chapters are full of interest, and comprise practically all that is known on the subjects. The vocabularies are arranged in groups, mainly on a regional basis, and embrace altogether no fewer than 274 separate languages or dialects, numbered consecutively throughout—a useful system which greatly facilitates reference. Notes are given at the end of each section explaining the local distribution of each language, and the volume concludes with a full bibliography. This forms a most useful *catalogue raisonné* of the literature of the subject, and indicates for each language the printed sources drawn upon in the compilation of the vocabularies.

All who know Bantu Africa must sincerely hope that Sir Harry Johnston may be enabled soon to complete his great book, the second volume of which will embrace his deductions and conclusions from his study, and will thus, if possible, possess a still higher interest for the philosophial student than that now before us. Anything like a critical appreciation of the work from a technical point of view must be reserved until its appearance. A. S.

Transsahariens et Transafricains.— Lieut.-Colonel Godefroy. Pp. 92. *One Map.* Paris: Émile Larose. 1919.

Colonel Godefroy examines anew the question of linking Algeria with French West Africa by railway. He also discusses the grandiose scheme associated with the name of M. Berthelot, which would make the Transsaharan line simply the first step in an all-rail route from Algiers to Cape Town. He does not believe that such a cross-African line would be a profitable concern, and as far as the Saharan section is concerned it is condemned as passing through the most arid part of the desert.

The author is however a firm believer in the necessity of linking up North and West Africa by railway. He writes with authority, for he is director of the Biskra–Tuggurt line. While leaving unsettled the question whether the "Transsaharan" should reach Insalah *viâ* the Wadi Saura or *viâ* Wargla, he takes it thence by the route already reconnoitred to Anhet and west of the Ahaggar (Hoggar) to the Niger at Tosaye (Burrem). The distance from railhead at Tuggurt to Burrem by this route is 1470 miles. M. Souleyre, an eminent engineer, has proposed a shorter route, going due south from Tuggurt through the sand-free "cleft" in the eastern Erg. Colonel Godefroy prefers the Wargla–Insalah trace, because it serves the principal oases and is the chief caravan route in the Western Sahara.

That there are no engineering difficulties to prevent the building of the line is now established, and it is one of the merits of this very lucid study that

Colonel Godefroy, with his expert knowledge, discusses the commercial and economic aspects of the project, and goes into detail with respect to the manner, cost and time required for construction. He believes that a narrow-gauge line could be built in eight or ten years with an expenditure of roughly £12,500,000. Colonel Godefroy, who is studiously moderate in his estimates, foresees great advantages to be gained by joining Mediterranean Africa with "nos Indes noires"; he does not however deal with the competition of sea routes, and it may be questioned whether the railway could carry merchandise from West Africa to the Mediterranean at rates as low as those charged by the shippers. The same doubt arises with respect to the proposed Tangier–Dakar railway, mentioned briefly and with approval by the author as enabling the journey from Paris to Pernambuco to be made in about ten days.

The map is clear and useful, but not quite what it should be. It shows some railways as in existence which are not yet built (*e.g.* the Tangier–Fez line); it does not show all the projected lines discussed by the author, and the Wadi Saura, frequently mentioned in the text, though marked, is not named.

F. R. C.

AMERICA.

The Illinois and Michigan Canal.— J. W. Putnam. Chicago: University of Chicago Press. 1918. *Illustrated.*

Dr. Putnam's study of the commercial connection of the Great Lakes and the Gulf of Mexico by way of the Mississippi and an artificial waterway includes an historical survey of the various plans and performances with the same end in view during the last hundred years. He points out that there was, a century ago, a great deal of public enthusiasm regarding canals, and that the coming of the railroad led to sudden and sustained decline of interest in such methods of transport until the present time, when economic pressure has brought about a revived sense of their potential importance. Not only labour troubles in the United States, but a growing realization on the part of the public that too much dependence is placed upon a single form of transportation, contribute to awakened consideration of waterways. The long distances of North America between thickly populated areas, the lack of good roads, and the increasing expenses of rail carriage render it a matter of public economy to take advantage of the water routes wherever they occur. The length of the Mississippi, the comparative ease with which the existing narrow channel between Lake Michigan and the Illinois River, a great Mississippi affluent, could be deepened for the passage of vessels of considerable size, are arguments in favour of this all-water system, so long discussed.

The author traces old negotiations, laments that, during many years, so much good money has been wasted upon "pork barrel" waterway schemes while this simple and obviously important work is neglected, describes the operation of the canal as constructed, and shows the effect upon economic conditions already brought about and in view if the suggestions for deeper canalization are carried out. He thinks that a 14-foot waterway is needed, and proposes the erection of state-owned electric power plants along the route.

L. E. E.

The Danish West Indies under Company Rule.— Waldemar Westergaard. New York: The Macmillan Company. 1917.

Dr. Westergaard had begun his researches into the early history of the Danish West Indies, a neglected chapter of colonial history, before the attention of Americans was drawn to the islands by their annexation to the

United States in December 1916. This volume, which deals with the history of the islands under the Danish West India Company, 1676–1754, is the first-fruits of his labour, and is to be followed by two other volumes dealing with the later history, which he has briefly summarized in a supplementary chapter of this volume. His work is based on extensive researches in original papers in the Bancroft Collection at the University of California and in the Danish Archives, and has been carried out with exceptional thoroughness. In addition to the narrative he has reproduced in appendices a number of important original documents and statistical returns; and reprints of early maps of the settlement add to the completeness of the volume.

The Danish possessions consisted of a group of very small islands, of which three only have had any importance—St. Thomas, annexed 1666, and colonized by the Company in 1672; St. John, annexed 1684, and colonized 1716; and Santa Cruz, bought from the French in 1733. Their history presents no exceptional features, but it is interesting, as is the history of all the West Indian islands; it is, in fact, the story of the growth of a typical West Indian colony. There is the same experimentation in crops as one finds in the case of other islands, beginning with tobacco and gravitating to sugar; the same labour problem with the same attempted solutions, first the colonist, then the negro and the slave system, with its cruel laws and peril of insurrection; the same natural difficulties, hurricane and earthquake; the same problem of trade policy and trade monopoly; the same struggles of the planters with the privileged Company. And Dr. Westergaard breaks off his narrative at the point where the Crown intervenes and buys out the Company and brings the settlement under royal control. It is an interesting story, made up of small incidents and partial aspects of the large problems of European occupation and development of the Tropics in the eighteenth century, when sugar colonies were especial objects of desire, and colonial policy aimed at bending subordinate communities to the interests of the parent country. If Dr. Westergaard completes his history with the same thoroughness he will make a very valuable contribution to the history of the West Indies. E. A. B.

GENERAL

Handbook of Travel; prepared by the Harvard Travellers Club.— [Edited by **Glover M. Allen.**] Cambridge, [Mass.]: Harvard University Press. 1917. *Price* $2.50.

All who are familiar with 'Hints to Travellers' will turn with interest to the pages of its Transatlantic rival. It contains a store of valuable information that should assure it a welcome from all travellers beyond the limits of the steamship and the locomotive. Perhaps the most striking contribution is William B. Cabot's "Camp and Travel in the North Country," which is given the first place. Its unfamiliar phrasing arrests the attention at once, and it is found to be crammed full with the author's own experience and the traditional love of the northern wilds of America. One is startled at first to read that the "wedge" and the "cone" are typical forms of tents, or to be told as a recommendation that in winter a double wall "turns cold remarkably," but soon realizes what is meant. Never have the potentiality and the romance of the elemental needs of life face to face with nature and the means by which they can be satisfied, been more strikingly presented. The description of the axe in its different varieties, each with shapely curves of its own that fit it for its special sphere of usefulness, is almost a poem. Fires, clothes, snowshoes and many other topics are handled in the same effective way. Then follow some

useful pages by Sinclair Kennedy on camp cooking, while John W. Worthington tells us of personal equipment, including arms and ammunition and "dead water" travel. Several authors unite to write of "swift water" travel, and there are detailed instructions for descending rapids in canoes which are by no means in accordance with popular ideas on the subject; but as the reviewer's experience of rapids is mainly confined to passing them on rafts, he is not in a position to express an opinion. Travel by pack-horses, dogs, and camels, is taken in turn. Under the first are included also mules and "burros" or, donkeys. Then follow essays on mountain climbing and hunting dangerous game, succeeded by a long article by three medical men on Hygiene, Medicine and Surgery; but though it contains a number of useful hints it is not long enough to give all the details on these subjects needed when qualified medical assistance is inaccessible. In the brief reference to typhoid fever there is no mention of the absolute necessity of the patient avoiding all solid food. Elsewhere it is stated that malaria recurring only on alternate days (tertian) is rare in the tropics. The reviewer has suffered himself repeatedly from Tropical malaria, both in India and South America, and only once contracted any other form than the tertian. The amount of quinine recommended is rather larger than is, in his opinion, usually necessary, but he is aware that the tendency of modern practice is in that direction. J. W. EVANS.

In this handbook there are three chapters devoted to surveying and mapping, the first of which is by R. W. Wilson on Determining Position by Astronomical Observations, the second by Oric Bates on Route Surveying in Open Country, and the third by Dr. A. Hamilton Rice on Traverse Surveys in Tropical South America. Mr. Wilson gives some of the more ordinary methods of finding latitude and longitude, with examples, followed by a set of useful tables. He does not attempt great accuracy, and states that the traveller he has in mind is one who, while pushing the main object of his journey, can spare a few minutes at noon to find his latitude, and a few more later on to obtain his longitude. Those who are desirous of carrying out an accurate survey are recommended to consult other works. He deals with the matter perhaps rather too much from a navigator's point of view, and recommends that Mercator's projection should be used for plotting the route. Others will not agree with him in this. The examples given are all taken with the sextant. The theodolite is referred to as well, but there are no instructions for its use. Still his notes are practical and concise, and contain much that will doubtless be useful. The late Mr. Oric Bates had considerable experience as a traveller in Egypt and parts of the Sahara, and gives some useful hints for quick mapping and sketching with the compass and plane-table. These are good so far as they go, but might have been a little fuller with advantage. For instance, nothing is said about "resection" or finding position from distant fixed points —so important in all plane-table work. His examples in the use of the traverse table rather unnecessarily repeat what has already been given by Mr. Wilson.

Dr. Hamilton Rice's notes are valuable, and should be of considerable service to those who, like himself, have to travel in thick tropical forest regions. He is well known in this country, and his papers and maps have appeared in the *Geographical Journal*. No one has done better work of the kind than he, or can speak with greater authority on this subject.

After the survey and mapping sections follow notes on Photography by Mr. J. T. Coolidge, jun.; Geography and Geology by Prof. W. M. Davis; Meteorological Observations by Prof. R. de C. Ward; Natural History Collecting by Messrs. G. M. Allen and T. Barbour; and Anthropology by Messrs. R. B. Dixon and A. M. Tozzer. E. A. R.

THE MONTHLY RECORD

EUROPE

Audibility of Gun-fire in S.E. England.

THE tremendous power of artillery employed during the recent war has provided opportunities for the systematic observation of long-distance acoustic effects such as have never before arisen, and it is interesting to note a valuable set of audibility observations by Mr. Miller Christy, of Chignal St. James, near Chelmsford, published in the *Quarterly Journal of the Royal Meteorological Society* for April 1919. The record covers the four years of active warfare, 1915-1918, and reveals the interesting and rather puzzling climatic feature that the audibility of the Continental firing was never apparent in winter, and in each year was practically limited to the months of May, June, July, and August, that is to the true summer (solstitial) period. The longest period of audibility was in 1917, when the earliest date on which firing was heard was April 22, and the latest September 6. But while this summer relation appears to hold for localities situated to the north and west of the source of sound, there is a good deal of evidence to the effect that in places to the south and east of the source of sound, as, for instance, Geneva, the firing was audible only during the winter months. The explanation of this curious seasonal effect, and still more of the periodicity shown as between England and Switzerland, has not yet been given. Another peculiar phenomena referred to in the discussion of the paper might be mentioned. The observations of quite independent persons in Essex, Sussex, and in Continental localities, including Germany, show that inside woods distant gun-firing is much more distinct than in the open. This is a difficult acoustic problem, and one can only surmise that the wood behaves as a sort of sounding-box.

AFRICA

Dr. Oudney's Grave in Nigeria.

Last year we printed in the August number of the *Journal* (p. 140) a communication from Mr. W. J. Gowers, briefly announcing the identification of the grave of the African traveller, Dr. Oudney, a companion of Denham and Clapperton on their historic expedition across the Sahara to the Central Sudan in 1822–24. Further particulars are now given in a despatch to the Colonial Office from Mr. A. G. Boyle, Acting Governor of Nigeria, a copy of which has been courteously sent to us by Lord Milner's instructions. The officer to whom the identification was due was Mr. E. W. Bovill, who, while touring in the Katagum Emirate, ascertained that the inhabitants of the village of Murmur (about 12 miles south-west of Katagum, according to the War Office map on the scale of 1/250,000) still had a tradition that a white man had died and been buried close to the village nearly a century ago.* The spot indicated coincided well with the details given in Clapperton's journal of the burial-place of Dr. Oudney (Denham's 'Narrative,' part 2, p. 33), and Mr. Bovill caused an excavation to be made which revealed the presence, about 2 feet 6 inches below the surface, of streaks of white powder containing (as was subsequently proved by analysis) calcium phosphate, probably derived from a skeleton. The grave has been surrounded by a wall, and it is proposed to erect a cross with the explorer's name inscribed. Some personal details about Dr. Oudney are to be found in Appendix XV. of Mr. P. A. Benton's 'Sultanate of Bornu.'

* Mr. Gowers' letter placed the scene of the discovery at the village of Chacharam, which we have been unable to find in the above-mentioned map.

AMERICA

Lakes of Epsomite on the Washington–British Columbia Border.

In the *American Journal of Science* for November 1918 Mr. O. P. Jenkins, of the Washington State Geological Survey, describes and illustrates two remarkable briny lakes known locally as the "Spotted Lakes," from their appearance when seen from a distance, especially in the dry season. Both are on Kruger Mountain, the larger being on the Canadian, the smaller on the American side of the boundary. The strange appearance of the lakes, which is well shown in the accompanying illustrations, is due to the presence of shallow pools of brine which form dark circular spots on an otherwise white surface. This last is due to an efflorescence of salts over a mass of black and treacherous mud, in which cattle have often been lost. During the rainy season the lakes are covered with water, and the spotted appearance is then only faintly visible. The smaller lake, which was most carefully examined, is only 4 acres in extent, with a depth of 30 feet. It lies in a basin without outlet, scooped out of metamorphic rocks, dolomites and shales. The spots have been found to represent inverted cone-shaped or cylindrical masses of salts which rise from a lower continuous bed sometimes 15 feet in thickness. The material known as epsomite occurs as a precipitation from the evaporation of waters saturated with magnesium sulphate, and since 1916 it has been exploited for commercial purposes, much of it being so free from foreign matter as to require only pulverizing and packing for transport by railway. The neighbourhood is rich in mineral deposits—largely pyrite and pyrrholite bodies, which, through oxidization by meteoric water and air, yield sulphates and sulphuric acid; these in turn apparently acting on the dolomite and other magnesian rocks and forming the magnesium sulphate, together with the less soluble calcium sulphate, from which a thin layer of gypsum beneath the epsomite has been derived. The Canadian lake is about 70 acres in extent, and the working of its salts has also been begun.

Sea-lions and Fisheries on the Coast of British Columbia.

Complaints of depredations committed by sea-lions in the salmon and other fishing-grounds on the coast of British Columbia led to the offer by the Canadian Government in 1915 of a bounty of $2 per head to aid in the reduction of the number of these animals. Shortly afterwards a commission was appointed by the Biological Board of Canada to inquire into the effect of this bounty and to study the sea-lion question in general. The Commission, which consisted of Dr. C. F. Newcombe, Mr. W. Hamar Greenwood, and Dr. C. McLean Fraser, carried out its investigations by personal visits to the sea-lion rookeries and the fishing grounds (especially Rivers Inlet and Barkley Sound), by examination of witnesses, and correspondence; but as all the desired ground could not be covered in 1915, its work was resumed in 1916 and led to more definite conclusions. Reports (with illustrations) based on both seasons' work are printed in *Contributions to Canadian Biology*, 1917, issued as a supplement to the 7th Annual Report of the Department of Naval Service, Fisheries Branch (Ottawa, 1918). They form interesting reading, shedding much light on the habits of sea-lions and their relation to the food fishes, and showing in a striking way the need of unbiassed scientific inquiry in a case where ill-judged action may lead to unfortunate results. The complaints against the sea-lion as a destroyer of fish are by no means new, for a somewhat heated controversy on the question was maintained in California towards the

end of last century, when the conclusion was reached that while the Californian species of sea-lion fed principally on squid, that more common in British Columbia (Steller's sea-lion) was responsible for the destruction of much food-fish. The matter has come to the fore more recently in British Columbia, where Dr. Newcombe and his son carried out a first investigation in 1913. The further inquiry of 1915 showed that between 1911 and 1913 the sea-lions in or near Rivers Inlet increased so much as to be a serious menace to the fishing industry, but that the destruction due to the bounty in 1915 had apparently had its effect in the increased "pack" of fish of that year. But the want of discrimination in the bounty was severely criticized, as it encouraged indiscriminate slaughter at the rookeries where the sea-lions did no damage, and left them more or less free to continue their depredations in the fishing grounds. The need to discount bias in the statements of the fishermen was also pointed out, as was the need of investigating the question whether by keeping down the numbers of the destructive dog-fish (proved to constitute part of the diet of the sea-lions) these might not be after all a positive benefit to the fisheries. The Commissioners agree that where it is evident that sea-lions are doing appreciable damage they should be driven away or greatly reduced in numbers, but deprecate action at other rookeries except under some organized plan by which the pups could be saved. The work in 1916 showed that in that year, apparently owing to the persecution met with in 1915, the sea-lions were very little in evidence on the fishing grounds, and that measures for scaring them away from these when necessary might suffice for the protection of the industry. At certain times of the year Steller's sea-lion undoubtedly eats large quantities of food-fishes, but there is as yet little or no evidence for the remainder of the year. In any case, by helping to keep down the dog-fish and other injurious species, he may do more good than harm on the whole, and the possible economic utilization of his hides and carcase is another reason urged against any plan tending towards total extermination.

AUSTRALASIA AND PACIFIC ISLANDS

Prospecting in South-Western Tasmania.

How far we still are from a complete knowledge of the surface features, and still more from a precise and detailed map of so old a British colony as Tasmania, is shown by a report which has been sent us (type-written) by the Director of Agriculture at Hobart, describing the examination by Mr. R. C. Hales of the country between the lower Gordon River, which enters Macquarie harbour on the west coast, and the western basin of the Derwent on the east. The object of the exploration was the discovery of the most suitable route for the opening up of a road from a navigable point on the Gordon River to Tyenna, one of the outlying stations reached from Hobart by the Derwent Valley Railway. (Near Tyenna is the newly established National Park; see *Journal*, vol. 53, p. 352.) The report gives information as to the general nature of the country traversed and its geology, which will be useful as this is one of the least-known parts of the island, a considerable tract north of the Gordon being marked as "Unexplored" in the large-scale map in four sheets issued by the Surveyor-General's Office some six years ago. This gives some help towards following the narrative, though by no means all the features spoken of are marked in it. The country along the upper course of the Gordon appears to be quite impracticable for roads, though a track passable on foot has been cut for some 20 miles, and by the choice of a better alignment might be further improved by the easing of the gradients. The Gordon itself flows

through a narrow gorge only 30 feet wide, with cliffs 150 to 200 feet high on each side. For the through route to the east the only feasible line seems to be a somewhat circuitous one south of the Gordon across the Olga plains, whose boggy nature is the only difficulty they present. Further on it is necessary to cross the Frankland Range by a somewhat difficult pass, on the route followed in 1811 by Surveyor Jones, marks of whose track were seen by Mr. Hales in the form of rotten stakes. Elsewhere the range, like its northern continuation, the Wilmot Range, presented a formidable appearance, being a succession of quartzitic crags crowning the summit, with deep rocky gullies on the flanks and no leading spur up which a track could be taken. Except at the Gordon gap the crest is practically continuous. On the far side of Jones' pass the route suggested leads down by easier gradients to Huon plains, and so to the existing track from Tyenna to Port Davey. This might perhaps be struck further south by a still more circuitous route, but the country in this direction needs further examination. Throughout the country examined no first-class land was seen, and very little timber of commercial value and accessible was met with. The prevailing rock formations are hard quartzitic schists in the mountains, with some exposures of limestone at low levels in the valleys, as also on the Gordon River. Alluvial wash consisting of quartz pebbles and of mica-schist was observed in the creeks of the Olga plain, and the plain itself consists of a soft sandstone traversed in places by quartz veins of considerable width. On the Uncharted River, a tributary of the Gordon, there is a band of clay-slate country. The only mineral indications were strains of limonite, and occasional depressions in the surface rocks, evidently casts of crystals of iron pyrites which had weathered away.

GENERAL

Atlantic Currents and Escaped Mines.

The Prince of Monaco has brought to bear his unrivalled knowledge of Atlantic circulation on the question of the fate of the mines which have gone adrift during the war in the West European waters and been carried out into the ocean, forming a menace to its navigation. In the *Comptes Rendus* of the Paris Academy of Sciences for 30 December 1918 he traced the course likely to be followed by such mines and defined the localities specially liable to be infested by them, illustrating his conclusions by a chart. The mines from the North Sea will in the main take a northerly direction towards the coast of Norway or the Arctic Ocean, whilst those from the Channel will either enter into the general circulation of the Atlantic or join those from the coasts of Ireland in their progress to the north-east. Mines from the more southern waters will all enter into the general circulation dominated by the Gulf Stream. They will be carried south past the Canaries and Cape Verde Islands and come under the influence of the Equatorial Current, and eventually of the Gulf Stream, passing near Bermuda and taking a north-easterly course back towards the region of their origin. Some will partake indefinitely of the circular movement round the Sargasso Sea, whilst those which reach the latitude of the English Channel will either be carried back towards the French, Spanish and African coasts and begin the circuit once more, or pass west of the British Isles towards Norway and the Arctic region, where they will be destroyed, no doubt, at their first encounter with the ice. The Prince calculates the time taken to reach the Canaries from the Channel at six months and for the whole crossing of the Atlantic at three years, the average rate being put at 5 miles per day.

The risk to ships from such wandering mines will remain therefore for a considerable time, for the Prince's experiments with floats have shown that these may continue their wanderings from ten to twenty years; but the mines will be gradually eliminated through encounters causing them to explode. The most dangerous localities will be (1) the waters off the outer coasts of South-West Europe, towards which there is a tendency for the mines to be driven by prevailing winds; (2) the region of the Azores and Sargasso Sea, *i.e.* the Central Atlantic between 32° and 43° N. lat., 24° and 50° W. long. The coasts of the United States are protected by the polar current which runs south as far as Florida.

CORRESPONDENCE

The Prismatic Astrolabe

WE much regret that neither of us was able to be present at the reading and discussion of our paper on "The Prismatic Astrolabe" which was printed in the *Journal* for July. We desire to express our thanks to the Society for the kind reception given to the paper, and to the various Fellows who took part in the discussion for their interesting remarks. At the same time we trust we may be permitted to reply to some of the criticisms of the instrument which were put forward in the discussion.

The most serious criticism urged against the prismatic astrolabe is undoubtedly that of Mr. Jackson regarding the elongated shape of the star-images owing to only half of the lens being utilized in the formation of each image. We candidly admit that if anything like the degree of elongation—three or four times the width—mentioned by Mr. Jackson were a necessary and unavoidable outcome of the construction of the instrument, that would, as he states, prevent the astrolabe from ever becoming an astronomical instrument of the highest precision. But in our trials no elongation whatever of the images was perceptible; the images appeared as circular as in the theodolite, and the only limit we found to the precision of the observations was that of time-taking, which of course is one common to all methods of time-determination. It is also noteworthy that Colonel Woodroffe does not record any experience of the difficulty mentioned by Mr. Jackson in the paper describing his use of the instrument on the Peru–Brazil boundary (*Geogr. Journ.*, 47 (1916), p. 345). We know, of course, that some degree of elongation of the images must theoretically exist; but we are able to state with absolute certainty that its amount was insensible in the instrument we employed in our trials. We think it most likely that the particular astrolabe used by Mr. Jackson was in some way defective. In that case his criticism can refer only to that particular instrument, and it would be quite unfair to urge it against the prismatic astrolabe in general.

We dissent from Mr. Jackson's statement that the astrolabe is not suitable for observing stars near to the meridian, owing to their slow motion in altitude. Stars near to the meridian which fall within the scope of the astrolabe can be observed with that instrument at least as accurately as with the theodolite. The rate of the star's movement in altitude being quite independent of the instrument employed, any greater liability to error of the observed time in the case of a star near the meridian, as compared with other stars, will affect equal-altitude observations with the theodolite in exactly the same way as it does those with the astrolabe. It is, however, important to note that in the method

of simultaneously determining time and altitude by equal altitudes of three or more stars, small errors of time in the case of stars near to the meridian are without sensible influence on the final result when combined with observations of other stars nearer to the prime vertical; for as Gauss long ago pointed out, "the essential condition is not so much that the precise instant when a star reaches a supposed place should be noted, as that at the time which *is* noted the star should not be sensibly distant from that place." We recommended in our paper that observations with the astrolabe should be taken on stars near the middle of the quadrants, *not* because of any unsuitability of the instrument for observing stars near to the meridian, but because of the greater number of stars available in other positions.

We are not quite clear as to what Mr. Jackson means by "determination of latitude apart from time." If he refers to the very rare case where an observer is required to determine his latitude without using any timekeeper at all, of course he is quite correct in stating that the astrolabe is wholly unsuited for such a purpose; while an expert observer with the theodolite would be able under the same circumstances to arrive at a fairly good result by the method of meridian-altitudes. But, in actual survey practice, the observer almost invariably possesses either a chronometer or a watch, and the fact that when he requires only his latitude he determines incidentally at the same time the error of his timepiece, so far from being a disadvantage, will in most cases be found to be of value in enabling him to keep a better record of its rate for future occasions, when a knowledge of the time may be an important element in his programme. Unless the observer is at a fixed observatory or at a triangulation-point from which the azimuth to another visible station is exactly known, even the method of meridian-altitudes requires a fairly exact knowledge of the time if a high degree of precision in the latitude is aimed at.

As regards the relative precision of transits over wires as compared with passages of two star-images, much depends on the observer's training and experience. For ourselves we think that the doubly-rapid relative motion of the images in the astrolabe is nearly balanced by the greater precision with which we can bisect a star with the horizontal wire of the theodolite, because we are accustomed to instruments of the theodolite type. But hydrographic surveyors accustomed to sextant-observations with an artificial horizon will very likely find it possible to attain a considerably higher precision of timing in the case of the passage of two images than in the case of the transit of a single image over a fixed wire. In fact, the similarity of astrolabe-observations to sextant-observations is a feature decidedly favourable to the introduction of the astrolabe into hydrographic survey-practice.

We wish we could agree with Mr. Jackson that under fairly steady conditions the bubble of the theodolite-level does not give much trouble. But one of our greatest difficulties in field astronomical work with the theodolite has been that under apparently steady meteorological conditions the movements of the bubble have been sufficiently rapid and large to introduce considerable uncertainty into the observational data.

With respect to the remark of Captain McCaw that only three stars are required to determine latitude, time, and altitude, we would point out that since three stars are the minimum number necessary for the determination, a mistake in any one of the three star-observations is fatal to the result, whereas if four stars are taken we have a good check, and a means of detecting a bad observation in the set. It is for this reason that we prefer on practical grounds to observe four stars in a set, rather than only the three which are theoretically

sufficient; and of course when four stars are chosen they should be 90° in azimuth from each other for the best result.

In employing the altitude of about 30° with the theodolite instead of the 60° used in the astrolabe, we chose that altitude for the theodolite which we think would most usually be considered the best in the field by surveyors using the equal-altitude method. In English theodolites, the direct eyepiece usually employed has twice the magnification of the diagonal eyepiece. Most surveyors would prefer to use the direct eyepiece both on this account and because it is convenient always to use the eyepiece to which one is best accustomed; and the use of the direct eyepiece involves the choice of an altitude much lower than 60°. Further, the lower the circle of equal altitude, the greater the number of stars available at a place, and this is doubtless the consideration which influenced Captain McCaw in saying that after he had used the parallel of 40° of altitude in Fiji, he was sorry he had not made it 30°.

Mr. Reeves is quite correct in pointing out that irregularities of refraction are likely to be greater at 30° of altitude than at 60°, but experience has led us to believe that the irregularities of refraction at 30° are commonly very small indeed, and we think that to the average field observer the disadvantage of greater risk of differential refraction at the lower altitude is more than counterbalanced by the greater number of stars available for observation.

As to the question of spider-lines *versus* ruled glass diaphragms, we quite agree with Mr. Reeves that the best results with the theodolite are to be obtained with spider-lines; indeed, we use these in all our ordinary work with the instrument. But in the particular case of this comparison, we wanted to make things as fair as possible to both instruments, and we considered that the slight decrease of precision caused by using the ruled diaphragm in the theodolite would just about compensate for the slight handicapping of the astrolabe by our lesser degree of familiarity with the latter instrument.

In conclusion, we should like to mention a suggestion which has been made to us, since our paper was printed, by Captain H. P. Douglas, R.N., of the Hydrographic Department of the Admiralty, with a view to rendering it possible to observe with the astrolabe while a breeze is blowing. Captain Douglas suggests that in addition to using the ordinary wooden wind-screen, a thin flat disc of glass, optically worked to true parallelism, should be placed so as to float on the mercury of the artificial horizon, and observations of the reflected image be taken through the glass. The glass would certainly protect the mercury from much vibration, and it would seem likely that the two reflected images (one from the glass and one from the mercury) would differ so considerably in brightness as to obviate any confusion from the duplication. We hope to make a trial of this suggestion, for if it should be found that observations can in this manner be made in a light wind without sensible loss of accuracy, a considerable extension of the conditions of applicability of the astrolabe would result.

JOHN BALL.
H. KNOX-SHAW.

August 12, 1919.

97°

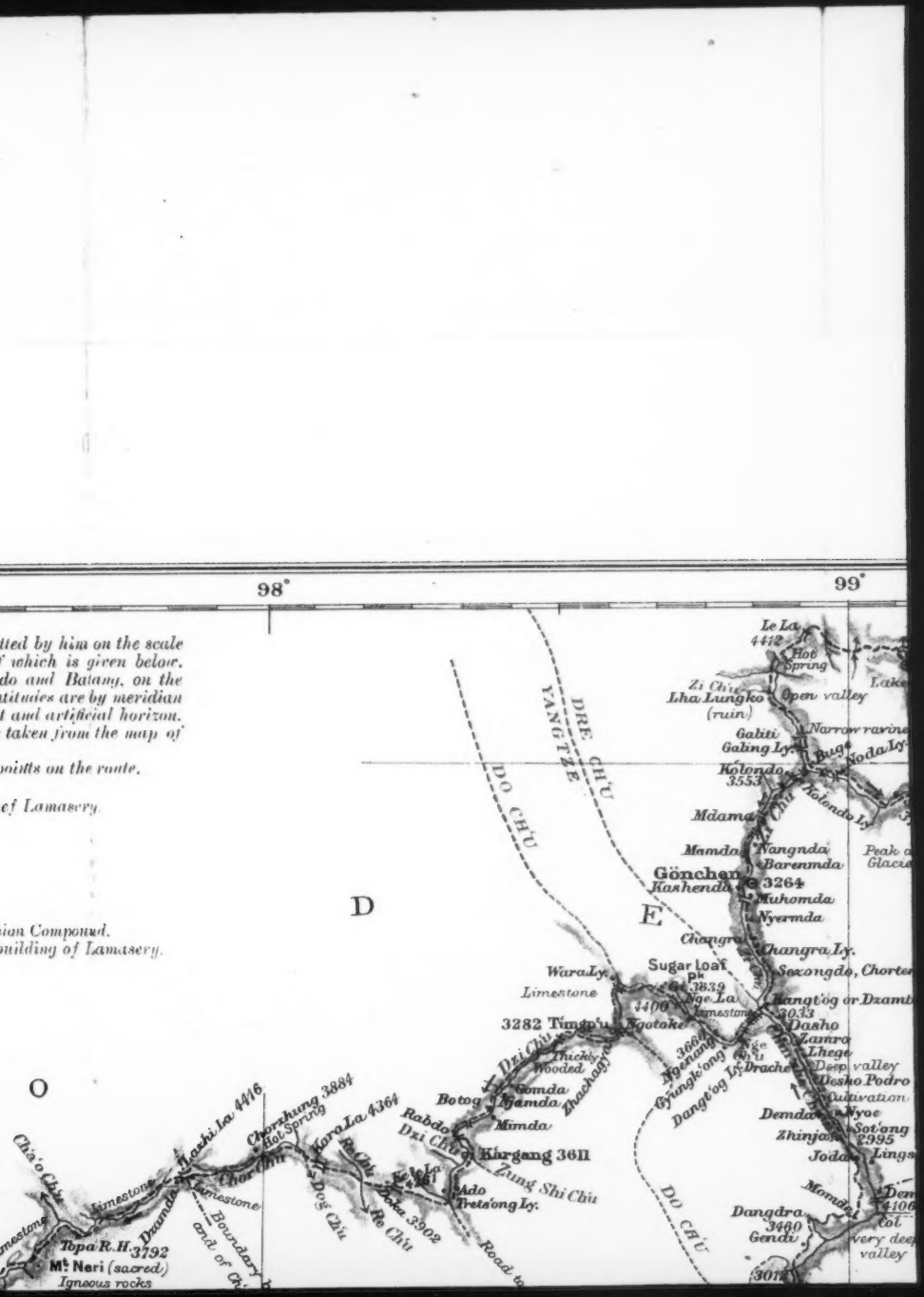
32°

NOTE.

This map is reduced from Mr. Coales' prismatic compass traverse plotted by hi
of 1 inch to 2 miles, and adjusted to his astronomical latitudes, a list of which is
The longitudes have been adjusted to the positions of Tachienlu, Ch'amdo and B
Survey of India 1/1,000,000 map of India and adjacent countries. The latitudes ar
altitude of stars (in most cases N. and S. stars) taken with a 6-inch sextant and arti
The route from Tachienlu to Dan was not surveyed by Mr. Coales, but is taken fro
J. Bacot published in his book "Le Tibet Révolté."

Heights are from aneroid, corrected by mercurial barometer at various points on t

	°	′	″	LATITUDES
Tachienlu ...	30	3	11	N. North side of Taoyin's Yamen and west of Chief Lamas
Taofu ...	30	58	58	C.I.M. premises.
Kaudze ...	31	38	3	150 yards south of main street.
Yilung ...	31	53	20	Side of Resthouse.
Gonch'en ...	31	49	2	Spur above Village.
Ch'amdo ...	31	9	11	E. gate of Lamasery.
Draya ...	30	34	43	South star only.
Batang ...	30	0	14	In front of northern dwelling in American Mission Compo
Pelyul ...	31	13	29	One altitude of south star. Behind uppermost building of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Kolonda 3553
Mdama
Mamda
Nangnda
Barenmda
Gönchen 3264
Kashenda
Muhomda
Nyermda
Changra
Changra Ly.
Wara Ly.
Sugar Loaf Pk 3832
Limestone
Sexongdo, Chorten
Dangt'og or Dzamti 3033
Dasho
Lamra
Lhege
Deep valley
Desho Podro
Cultivation
Demda
Nyoe
Sot'ong 2995
Zhinjo
Jodan
Lings
Momda
Dangdra 3460
Gendu
Tsa Chu
Dzi Chu
Thickly Wooded
Gomda
Mamda
Zhachagya
Botog
Rabdo
Mimda
Kargang 3611
Zung Shi Chu
Ado
Tretsong Ly.
Dzi Chu
Ngenang
Gyungk'ong Ly.
Drache
Chorzhung 3884
Hot Spring
Kara La 4364
Re Chu
Dog Chu
Dzeka 3902
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Topa R.H. 3792
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Igneous rocks
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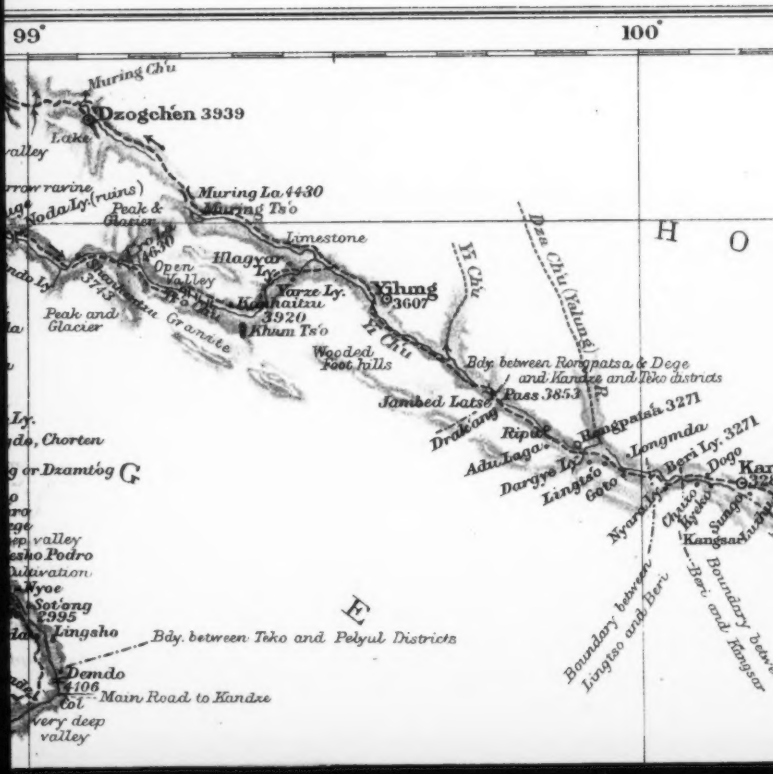
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Yihung 3607
Yi Chu
Dza Chu (Yihung R.)
Peak and Glacier
Granite
Khum Ts'o
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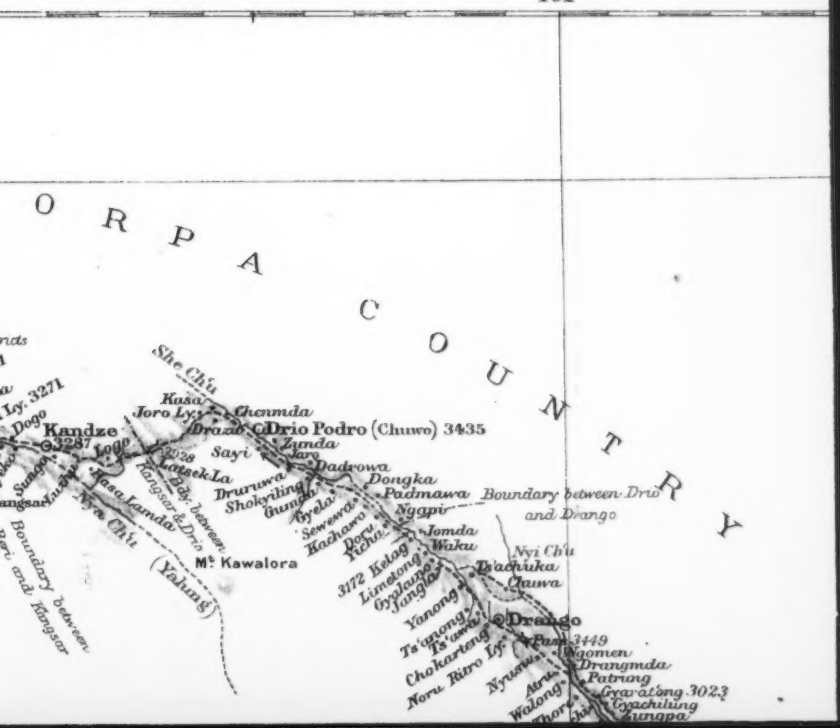
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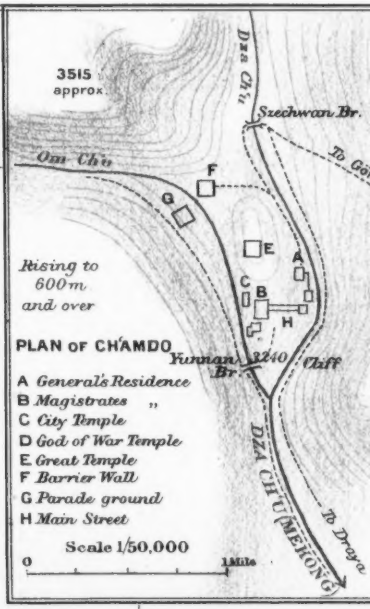
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F Barrier Wall
G Parade ground
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Main road to Draya
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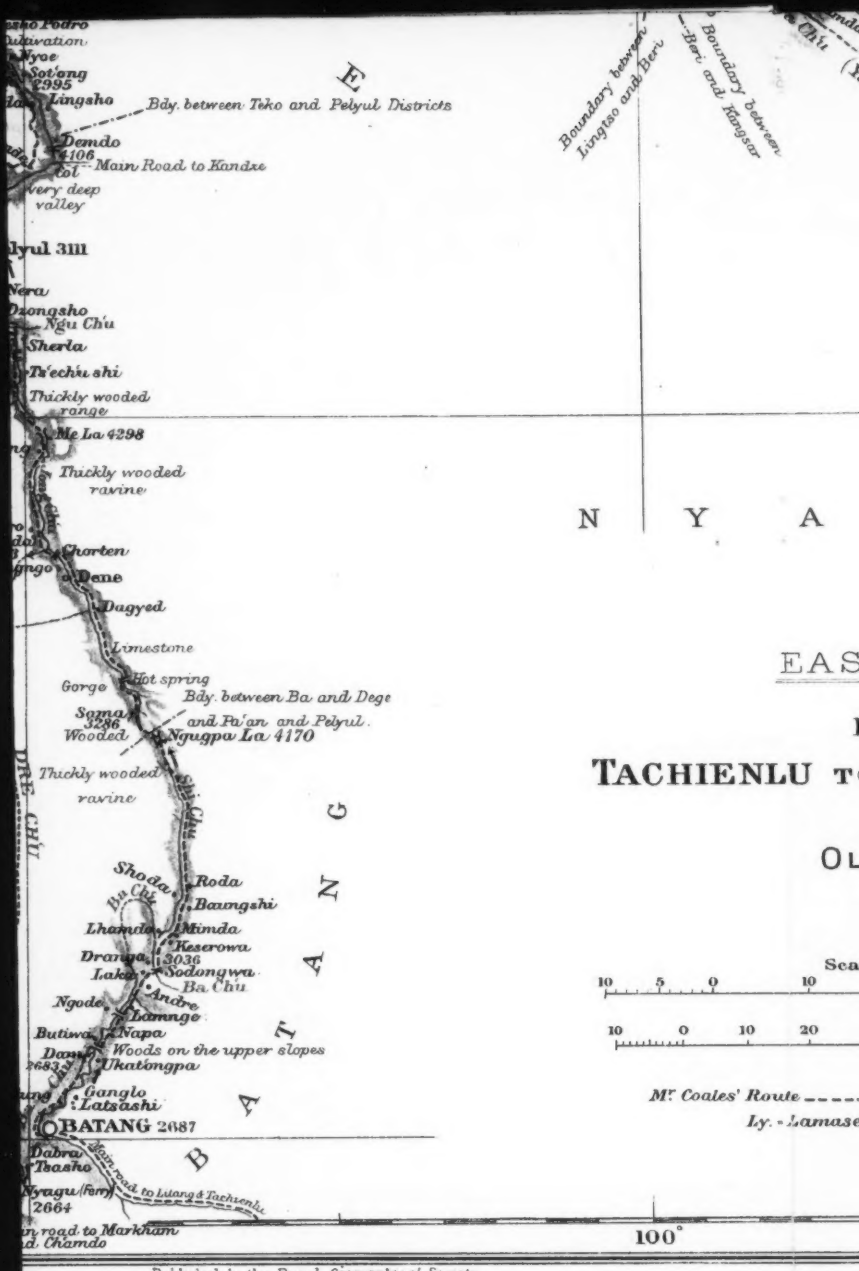
100°
Zilling Tso
T I B E T
Tsugri Nor
Giama no Tso
Kiwoché
Chamdo
Draya
Pasoichen
Gourtso
Kandse
Drango
Dasi
Pakyu
Bamed
Tachienlu
Hokow
Batang
Lhasa
Brahmaputra or Tsangpo
SZECHWAN
R. Yangtse
R. Yalung
Sadiya
Talap
BHUTAN
Darjeeling
NEPAL
R. Brahmaputra
A S S A M
Myitkyina
Tsili
YUNNANFU
BENGAL
Bhamo
Y U N N A N
Tropic of Cancer
R. Chindwin
R. Irrawaddy
Lashio
Red R.
CALCUTTA
Alon
Myingyan
MANDALAY
B U R M A
R. Mekong
FRENCH INDO CHINA
BAY OF
BENGAL
Prome
R. Sittang
R. Salween
RANGOON
S I A M
Scale 1/20,000,000
Railways
Basseim

Chorzhung 3884
Hot Spring
Kara La 4364
Rabdo
Dzi Chu
Kargang 3611
Botog
Mamda
Mimda
Zung Shi Chu
Ado
Tretsong Ly.
Dog Chu
Re Chu
Road to Gonjo
Boundary between Chamdo & Lhato and of Changtu and Rungpu
Limestone
Dangtog
Gyang
Desho Podro
Cultivation
Demda
Nyae
Sotong
2995
Zhinjo
Jodai
Lingsho
Momdo
Demdo
4106
Dangdra
3460
Gendu
DO CHU
very deep valley
3012
Pelyul 3111
Gyedong
Dega
Nera
Dzongsho
Cultivation on Alluvial cones
Ngu Chu
Ronge
3110
Sherla
Scattered houses
Tr'echu shi
Thickly wooded range
Me La 42
Obtang
SANAI
Thickly
Boundary between Chamdo and of Changtu & Chaya districts
Boundary between Draya and Gonjo and Chaya & Kung Districts
Ma Chu
Garsi Podro
Komdo
2973
Pungngo
Chorten
Dene
Road to Sanai
GONJO
RAYA
Lab Chu
Chom Chu
Yentaitang
Donggu
Su Chu
Ruins
Gyang Ling Ly.
Budongwa
Lhagongwa
Rangdrong
Ruins
Satawa
Drodzo Ly.
Midwa
Draya
(Chaya)
4673
Gopa
Gopal
Tilewa
Chorten
Donghowa
Shingkawa
Me Chu
Lhagongwa
Ruins
Ruins
Chorten
Main road to Garumdo and Batang
Uyemi La 4454
Gonjo Dzong
3607
Rangu
Kongsa
4255
Bungkhor
3725
Bungkhor Chu
Bungkhor
Road to Sanai
Open grass Country
Sandstone
Sandstone
Do La 4443
Bdy. between Gonjo & Markham & of Kung and Ning Chang districts
Plain
Do La
Lhato
4122
Limestone
Wooded ravines
Gorge
Taragamda
3812
Suti Ly.
Ore
Kemo
Tsong
Drangowa
Rasa
Thanagy
Chushugang
Grise Ly.
(Waloka)
Palowa
Omdawa
Ukagang
Limestone
To La
4742
4708 Drawa
Boundary between Ba and Markham
Rishingdo
Wooded ravine
Shisongkong
Gorge
2664
Nyagu (Ferry)
Main road to M and Chamdo
Gorge
Thickly wo
Ngode
Butiwa
Dam
2683
Sulolung
BATA
DRE CHU (YANGTZE)
MARKHAM
R. MEKONG
98°



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EASTERN TIBET

ROUTE FROM
LU TO CH'AMDO AND RIWOCH'E

Traversed by

OLIVER COALES.

1916-17.

Scale 1/1000,000 or 1/ M.

10 20 30 40 50 60

Miles

20 30 40 50 60 70 80 90 100

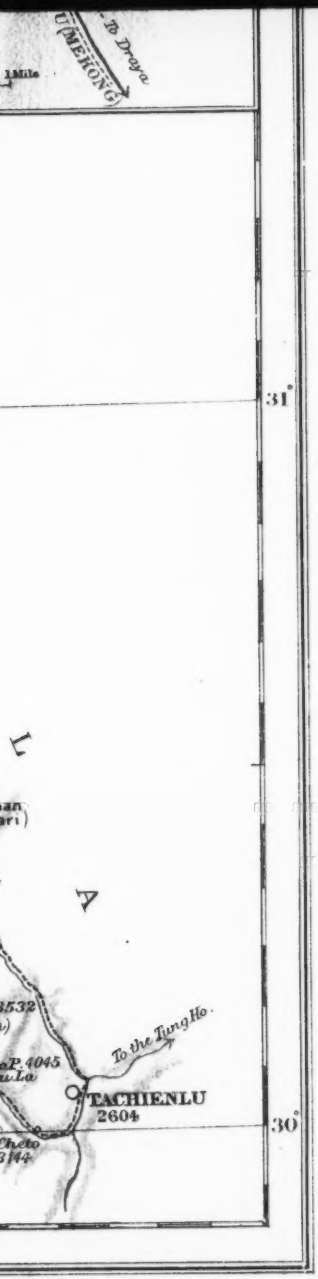
Kilometres

...de ---------- *Heights in metres above mean sea level.*

Lamasery *Br. Bridge.*

101°

H Main Street
Scale 1/50,000
0
1 Mile
Boundary between
Dau and Luho
Grase Chuka
Trangra or Goto
Tsime
Drato
Lgra
Zuno
Dau (Tao Fu) 2814
Koa
Shao
Gota Ly. (Taining)
Paunei (Bamed)
3397
Pass
Haitzu Shan
(Mt Zharari)
Trampadrong 3532
(Changpachan)
Chota P. 4045
Gyu La
Chota
3144
H
A
L
102°



EASTERN TIBET
Coales.